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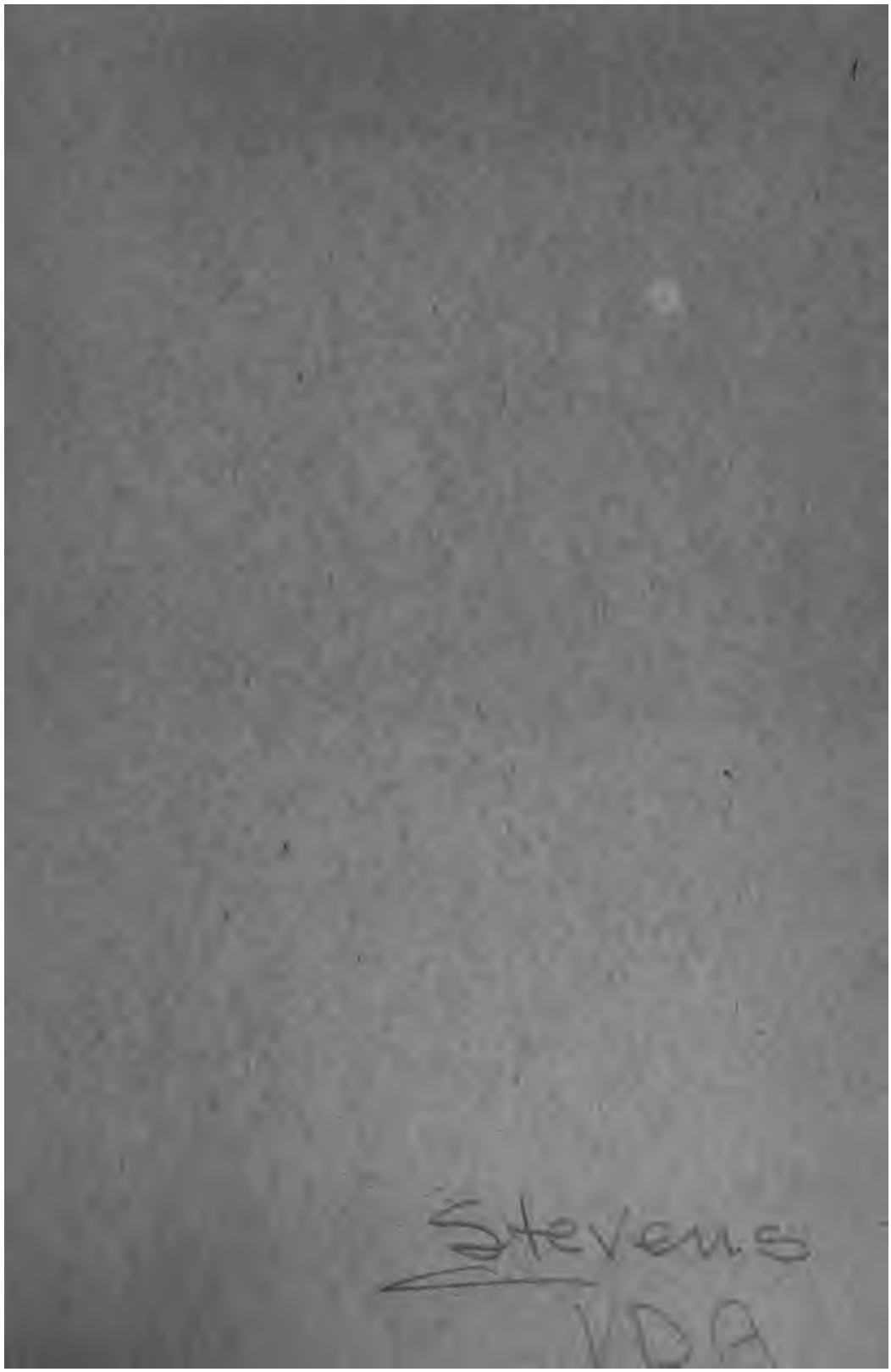
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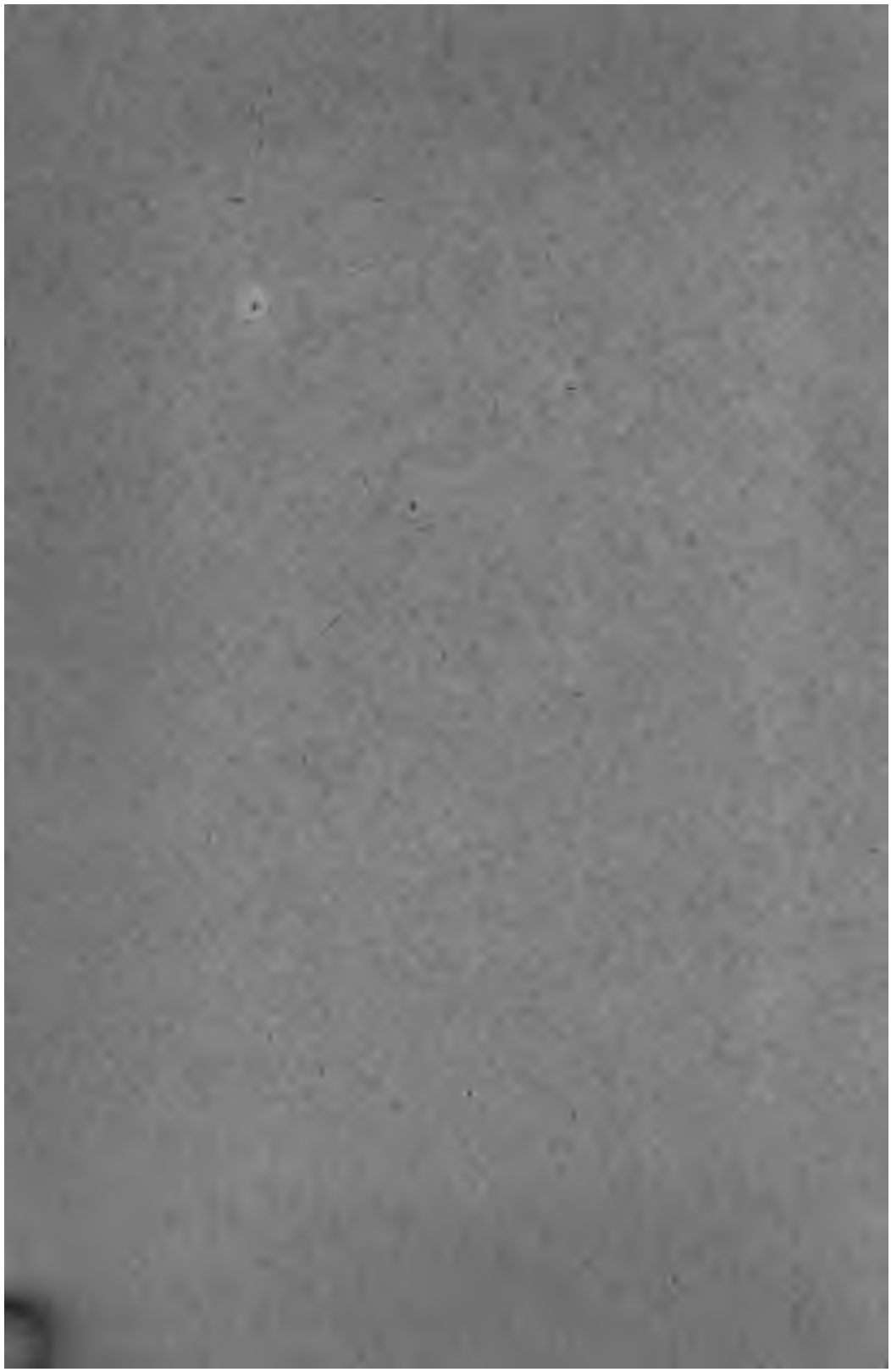

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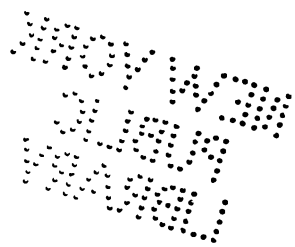

THE STEVENS INDICATOR.

VOL. IX. JANUARY, 1892. No. 1.

COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

IV.—LECTURE ON TRANSMISSION OF MOTION—ABSTRACT.

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HAVING made all that relates to transmission of motion, especially by shafting and belts, a study, and, in fact, my chief work during many years, I might be expected to go into the minutia of the subject; but in so limited a course as this, I can only treat it generally, and show you how to proceed to work out for yourself what you may require.

When you are called upon to design or erect the shafting or mill gearing required in any establishment, the nature of the work will, in a measure, govern the speed you may adopt for the line shafts. Line shafts for operating machine tools should have a speed of 120 to 140 revolutions per minute. This speed will not call for any pulley on the line exceedingly large or inconveniently small. For wood-working machinery and brass work, 250 revolutions per minute will result in convenient and inexpensive pulley sizes. Cotton and woollen mills can be better served with from 300 to 400 revolutions in some cases; but the head shafts of lines 1,000 feet long, may require a diameter of 4½ or 5 inches, and the longer the shaft the more trouble will come from high speeds. High speeds

demand more careful lubrication, more cast iron in the bearings to carry off and dissipate the heat, and result in more danger from fire

The rules and regulations laid down by the New England Insurance Companies regarding mill buildings and their equipment, will give you better information in regard to fire risks than most text-books. Obedience to the building laws of insurance rules ("Minutes," as they are called in England,) cannot be neglected. Bear in mind that ignorance of existing laws is considered no excuse for breaking them. Municipal authorities, for the protection of citizens, are obliged to throw about their municipalities legal limits to what can be done to prevent one citizen prejudicing the life, health, or comfort of others.

What you can do legally must be familiar to everyone of you who aim to be mechanical engineers. You will find instances where large sums have been expended in doing quite innocently what, when done, has been found to be illegal. This has happened in electrical transmission, in steam and compressed air transmission and in many other engineering constructions.

There are questions to be settled where speed is the controlling question in what can be done. In designing modes of transmission you will be called on to decide between high speed and light journal bearing pressure, or, greater load on the rubbing surfaces with slower motion of the parts in contact. Each problem must be worked out for itself; but I can assure you that you need not err if you refer to similar cases, or, better still, consult the authorities that have been text-books to you in your studies. Your professors have done more than most other teachers of mechanical engineers in clearing away many of the false ideas common in text-books in relation to frictional resistance.

In former lectures to this class I called attention to the innocent error made by Professor Ball in his lectures on mechanics, in showing that when any hoisting machine of simple construction is not capable of overhauling by the load, as in the differential pulley blocks in worm and worm wheel gearing, it is owing to a fact which he gives as a law, that the inability to overhaul points to a loss in efficiency, that when the efficiency falls below 50 per cent. such simple trains will not overhaul. It is needless for me to do more than to state that your teachers have thrown more light on this subject than any other authorities, and their teaching will, I am sure, have been already well-grounded in your minds.

When I myself first had anything to do with a machine shop it was in connection with a rolling mill, where ordinary bar iron was made, and connected with this same establishment there happened to be one of the few wire mills that were then in operation west of the Allegheny Mountains. The erection of this wire mill, as well as some other adjuncts to the rolling mill, necessitated the construction of lines of shafting which were turned in the machine shop at that time by an ordinary hand lathe, there being very few engine lathes available.

From that early experience my attention was directed towards building locomotives, and for a number of years I was employed as foreman, or superintendent, of one of the large locomotive shops of the West. In this same establishment the manufacture of line shafting and hangers and couplings had been conducted as a specialty, but in a manner that was very far from perfect.

After about five years' experience in this latter employment, I came East and took service with the then firm of William Sellers & Co., in Philadelphia, as their chief engineer. Now it is to this particular firm that we are indebted for most of the improvements that have been introduced in the transmission of motion by means of line shafting and mill gearing in a very superior manner. They have been leaders to the highest condition of the art at the present time. They were the first to manufacture what is known as ball and socket or self-adjusting hangers, which enabled line shafting to be erected cheaply, and permitted the use of very long bearings for the shafts, much longer than was possible in ordinary rigid hangers.

The most serious trouble connected with the manufacture of ine shafting lay in the difficulty of fitting couplings to the shafts, which couplings were to join the independent lengths into one long line. The coupling used at that time, and the only coupling then used to any advantage, was that known as the plate coupling, which consisted of two flanged hubs, one half of each coupling being permanently attached to the end of each shaft and the halfs afterwards united by bolts that had been carefully reamed to place so as to permit no possible motion at the point of juncture. An absolutely perfect coupling for shafting calls for something that must be as strong, if not stronger, at the coupled joint as the body of the shaft. This is quite possible with the old plate coupling, provided the work is properly done, and the couplings themselves are right-

fully proportioned, but it calls for very superior workmanship and great care in fitting. It necessitates, also, the use of open-sided, or hook hangers, which will permit the separate lengths of shafting to be lifted into their bearings without the removal of the coupling.

Many engineers had worked on the problem of obtaining or inventing some coupling which should have all the qualities of the plate coupling, but yet would have the advantage of being easily removed and replaced. It so happened that it fell to me to be the one who originated the coupling that seemed to answer all the requirements, and the invention known as the double cone vice coupling, now so largely and generally used, and the basis of many attempts to imitate it, has been accepted as the standard of excellence as to qualities required in a coupling for line shafts.

The double cone vice coupling did away with the accurate hand work required with the old form of plate coupling, and permitted machine work to take its place. It claimed to be equally as rigid as the plate coupling, and yet be readily removed. It did not deteriorate under repeated removals, and, in fact, seemed to answer all the requirements called for.

The important service, however, done to the art of making shafting by the invention of this coupling, was not confined to it alone. It enabled much improvement to be made in the form of hangers. It permitted the use of double-braced hangers, that is hangers of the V form, which would carry the bearings with equal steadiness, and required much less metal in their construction, and yet permitted the ready removal of the shafts for repair or alterations of the pulleys on the line. The invention of these improved hangers, coming as they did with the coupling, permitted the manufacture of shafting to be taken up as a separate and distinct line of mechanical industry, and now there are many establishments in different parts of the country, confining their work almost exclusively to supplying the wants of the community in reference to all that goes to make up the equipment of factories in shafting, couplings, hangers, pulleys and gearing.

It is now more than forty years since Joseph Bancroft, the inventor of the ball and socket hanger, or the hanger having the property of self-alignment with the shaft that rotates it, began the manufacture of this article. When he had invented it and put it into convenient shape, he endeavored to dispose of the patent right to

manufacturers of shafting, or, rather, to makers of machinery, in various parts of New England, but without success, and none were made and erected until he began the manufacture of them in an extended way in connection with William Sellers, as under the firm of Bancroft & Sellers.

The essential merit of the invention lies in the possible use of the extended surface of the bearing. When it is possible for a bearing to be so placed as to insure a uniformity of pressure over the whole length of the box, that length may be greater than in the case of rigid bearing in which the rigidity limits the length to a very considerable degree.

It was about the same time that this hanger was invented that white metal was introduced as the material for the bearings; but the makers of the swivel hangers found it useless to line the bearings with white metal, provided the length of the bearings in proportion to the diameter of the shaft could be long enough to keep down the pressure per square inch upon the surface of the bearings to something less than 100 pounds per square inch. If oil can be continually kept in a bearing between the metal of the box and the metal of the shaft, it makes very little difference what metal that box is made of.

This was proved in a remarkable way by an improved step for vertical shafts, to which I will presently call your attention; but now I wish to particularly impress upon your minds the theory that influenced the makers of these hangers to persist in delivering to their customers unlined bearings made of good quality of cast iron.

When you leave this school and go into actual practice of your profession, you will find many makers of shafting, and the different attachments connected with shafting, who will advocate and advertise babbitt boxes in the hangers, and you will hear of instances in which the unbabbitted boxes have given more or less trouble from cutting and heating. The hangers, as made by Bancroft, first, and continued afterwards by the firm that succeeded him, were made always with an appreciable clearance between the box and the shaft, a loose fit being quite essential for the free admission of oil. On top, at each end of the long bearing, are always placed a tallow cup covered by a metal plate. In these tallow cups a thicker grease is used than would be employed as an ordinary lubricant. Oil is usually fed to the centre of the bearing and distributed by grooves in the upper box, but the tallow cups are safety devices. In case

the box is neglected and warms in the slightest degree, this thicker lubricant will be melted and pass in a fluid state into the bearing and supply the deficiency in the oil. When you find a bearing seemingly properly made, of sufficient length, according to modern ideas on this point, and yet persistently heating when carefully attended, you will find that the pressure on the bearing is either too great, the velocity too great, or the fit of the box on the shaft too tight In the case of head shafts where the main belts coming from the engine or source of power are heavy, and cause very great pressure or where one line distributes its power to another one at some distance by horizontal belts, it may be advisable to make the boxes of a larger size, and consequently of thicker metal, than if made of unlined metal and recessing them for babbitt, to so line them with this white metal, but, in point of fact, I myself always advise head shaft boxes being made of bronze, as a stronger metal and capable of being recessed for the babbitt metal, and lined, or made with bronzed surface, as circumstances may demand.

You will find, I think, if you watch closely the effect of boxes lined with babbitt metal that the softer metal is apt to catch and hold all gritty dust, and that the shaft will wear down under the action of the grit that is held in the softer metal. But this need not deter you from using such precautions, but should make you the more careful to protect the bearing from material that would be likely to injure it.

If your attention is drawn toward railroad practice and you look back at the history of constructive engineering, in reference to locomotives and cars, you will find that the present long-bearings used and the larger diameter of axle has been introduced within the last quarter of a century. Mr. James Milholland, of the Reading Railroad, was the first one to introduce the long-bearing on car axles, and he did it from consultation with me, and from his experience gained with line shafting constructed with the long boxes. Bearings that are swiveled and can accommodate themselves to the journal should not be less than four diameters long; that is, four times the length of the diameter of the shaft that is used in them.

When Mr. Bancroft first began the manufacture of such hangers, he made them 5 diameters long, but it has now been thirty-five years at least since the change was made that reduced them to 4 diameters, as being sufficiently long for safety.

As bearing upon this matter of the durability of shafting bearings, I will now call your attention to the experience gained by the steps of vertical shafts. In former times, and many makers still continue the practice, these steps were made small in diameter, to diminish friction as was thought. With small diameter, of course, there must be heavy pressure per square inch of surface. It was Mr. Mason, of Taunton, Mass., who first conceived the idea of making the bearings at the foot of an upright in such a manner that the step upon which the bearing rests can accommodate itself to the surface rotating upon it. He then thought that it would be wise to increase the diameter of the revolving step to such an extent as to give an area sufficient to reduce the pressure to 100 pounds per square inch upon the step and to arrange a possible free circulation of oil between the surfaces. Steps made in this manner were put in use very much against the advice of the manufacturers, by whom they were constructed, but they were found to work so well and to give so much satisfaction, running so much lighter than the ordinary step, that they soon came into general use, and when General James came to Philadelphia from New England to build the Gloucester Mills and the large mills at Lancaster, in about 1850 or 1851, he brought with him this system of vertical step, self-oiling and self-adjusting.

Some of these steps which, in older practice, would have been only 4 or 5 inches in diameter, were increased to a diameter of 18 or 19 inches, and I have had an opportunity of examining such bearings after they have been in use for over thirty years, but found that the tool marks upon the metal bearing surfaces were not worn off, the whole step having the appearance of having been floating in oil and not coming into metallic contact.

In the endeavor to accommodate enormous weights it cannot be conveniently arranged by mere increase of diameter without obtaining too much angular speed from rotation. Many devices have been introduced to force oil by pumps in between the rotating surfaces and so compel the bearing to be continually supplied with the lubricant which shall separate the metals from each other.

I should advise you to study this matter carefully, to think of he practice that obtains in regard to the propeller shafts in large steam vessels, and to note that in this case amplification of surface has been obtained by what is known as collar thrust; a succession of rings turned in a shaft are made to take the end pressure of the

propeller, which in many cases results in a strain far greater and more intense than is likely to be obtained in any ordinary case upon land in the steps of vertical shafts.

Having been for so many years engaged in the manufacture of shafting and mill gearing, it would be wrong if I did not devote some of my time in imparting to you some of my knowledge in regard to the matters that are of especial importance to be borne in mind.

In the first place, in regard to pulleys, the early makers of solid cast-iron pulleys put themselves to some trouble to make the arms of the pulleys crooked, generally S-shaped, with the idea that the shrinkage strains in the pulleys did not permit of a straight or radial arm. Those who have gone extensively into the manufacture of pulleys soon found out that by a mixture of the metals for pulley work they could easily manage the matter of internal strains, and eventually the straight-arm pulley made of the right kind of metal became the rule and not the exception. Those who have spent much money in getting up a set of patterns for pulleys have been careful about calculating the strains that come upon them and adapting the amount of metal to the work to be done, making them lighter for single belts and heavier for double belts.

But in regard to the requirements of pulleys, I should urge each one of you, whenever you can, to obtain the price lists and catalogues of these different pieces that together make up the shafting list, from the makers of reliable machinery of this kind, and study them carefully, comparing their size, their width and their prices. For ordinary pulleys, and driving machinery that is held in place by set screws, there need be less said than about those that are placed upon the head shaft and receive the first power from the engine. These large pulleys must be securely fastened, and previous to the process which I am now about to describe to you, reliable makers always fitted them with what are called "forced fits"—that is, to have the eye of the pulley bored to a size somewhat smaller in diameter than the shaft upon which it is to be forced, according to a certain well-defined amount which is not usually expressed by the workmen in the shop in fractions of an inch, but in thicknesses of paper; thus, to fasten a pulley upon a shaft that is, we will say, four inches in diameter, the part of the shaft where the pulley is to be seated is made about the thickness of ordinary foolscap paper ($\frac{5}{1000}$ of an inch) larger in diameter than the eye of the pulley that is to be forced upon it. These pulleys are then put into place by a screw-forcing

press that draws them on so tight as to almost render the use of a key superfluous. Keys that are fitted to these tightly pressed on pulleys are usually made quite parallel. They do not of necessity bear top and bottom on the shaft of the pulley, but they do fit very closely sideways in the spline on the shaft.

Some years ago a process of fastening pulleys was adopted by my house, which consisted of splitting the hub of the pulley and arranging bolts to draw the split parts together without splitting the rim of the pulley. Such pulleys are cast with cores making the division in the hub and arranging for the bolts that are to draw them together, but leaving thin continuous metal where the eye is bored. Then after boring, the pulley is split by driving wedges in and parting the thin metal outside of the eye. Such pulleys to be put in place are keyed open by wedges, when they can be easily put to place, and knocking out these wedges they spring together again.

In some experiments tried with this kind of fastening in which the pulley was bound to the shaft only by these clamping bolts and not by any keys to prevent rotation, it was found that a 60-inch pulley placed upon a 4-inch shaft could be made tight enough to enable a double 12-inch bolt to be broken under the strain of causing rotation by slip of the pulley on the shaft. Since the introduction of this kind of split hub pulley, the practice has been carried to a greater extent to all the various pulleys used for driving machine tools as doing away with much of the costly fitting incident to the old process.

There has also been much improvement made in the method of manufacturing pulleys in halves that can be readily taken off the shaft or put back on it. Pulleys, too, are now being made of wrought-iron, especially in England where manufactories are devoted entirely to the production of such pulleys. Some very good wooden pulleys are also to be had.

Our thoughts about pulleys lead us naturally to consider the question of belts that are to run upon them. Pulleys are made straight on the face or crowning, called in trade, "straight face," or "high face," the one for the purpose of shifting belts, the other—the high—for a stationary belt that does not shift.

Where leather belts are used upon pulleys, and those belts are only single ply in thickness, the hair side of the belt should always be placed next to the pulley, and the flesh side out, for two reasons: the first is, that the hair side of the belt is more durable and

smooth, and gives the best adhesion, while the other important reason is, that the flesh side is more elastic and allows the belt to stretch on that side as it passes over the small diameters of the pulleys.

There is another question about belts and pulleys to which I wish you to give much thought, and that is the undesirability of driving from one engine shaft to another shaft by two separate belts from pulleys of the same diameter, or driving any machine by two separate belts, one on each side. You will find that many of the fan blowers that are on the market are provided with driving pulleys on each side, the intention of the makers being that two drive belts in this manner equalize the strain upon the shaft and prevent an undue strain upon either of the two bearings. I cannot be too emphatic in condemning this method. I could tell you of cases where machinery driven by two belts has taken very much more power to drive it than when one belt only was used.

I was called at one time to look at a forging machine for making bolts, driven by two belts from the countershaft; there was a single belt from the main shaft to the countershaft. I was told that the users had much trouble with the main belt to the countershaft, leading them to assert that the machine had been underbelted, and they proposed to put larger pulleys on to give more belt power. The two belts had been applied for the purpose of getting sufficient power. They had not tried driving by one belt, but when they did, at my request, they found that one belt would drive just as well as the two; in fact, so well that the main belt, thereafter, gave no further trouble. Pulleys cannot be made so accurately of the same diameter as to enable two belts, side by side, to run properly. In point of fact, two belts, even if made at the same time and of the same material, have not the same degree of elasticity and one will act as a retardent on the other.

Bearing upon this subject of belt driving, you will have brought to your attention the rope driving now so common in many places in England particularly. I have seen one case where the engine shaft had a grooved drum upon it driving the dynamo of a large electrical station with 40 hemp ropes, each about 1½ inches in diameter. This, with many engineers, is liked very well. There is quite an amount of literature now appearing upon this subject which it would be well for you to look up and study. While in England last summer I found one large electrical establishment claiming the

originality of driving by means of continuous rope belt passing backwards and forwards from the driver to the driven pulley over the various grooves, and finally carried back over one idler to the opposite side of the driver.

These makers were much surprised when I told them that was a common practice in America; that they could not patent it; that I had seen it exhibited in the Franklin Institute on a dynamo which was brought before the Institute at the time that President Morton, of the Stevens Institute, was secretary of the Franklin Institute. To two of these English makers I had the satisfaction of sending afterwards some of the literature issued by the rope makers in America who have developed this industry to a great extent.

You may have your attention called to the use of wire ropes for power transmission, and here you will meet with the recent developments of the case, where some of the large transmission in Switzerland, where wire rope transmission has been so long and so successfully used, are now being abandoned for electrical transmission. You might make a note that the extent of the transmission by a single wire rope in Switzerland is acknowledged to be about 333 horse-power, by means of a single wire rope; usually 1,000 horse-power is transmitted through three ropes; beyond this, it is not economical.

To get up a bill of shafting ready for the manufacturing shop that is to make it, you can save much trouble by the observation of a few simple rules.

In the first place, I strongly advise against making the spans, or lengths of shafting from hanger to hanger, more than from 8 to 9 feet in almost all cases. I can assure you that a shaft, 2 inches in diameter, 10 feet in length between hangers, with a pulley in the middle of it, driving looms on either side, will be so inefficient that the knocking off of one loom will invariably stop all the other looms on the same shaft, which is not the case when the span is reduced to 8 feet.

Where you have only the transmission of power, and not any lateral strain from belts, the distance can be increased, and there are cases in which it is admissible for shafts of, we will say, $2\frac{1}{2}$ to 3 inches in diameter, to put a distance of 12 feet between the centres of the hangers.

In regard to the size of the shaft, I would call your attention to the table issued by some of the leading makers of shafting, in

which they give the revolutions of the shaft per minute, and the sizes of shafts manufactured, with the horse-power that it is capable of delivering.

This table, in the case of William Sellers & Co., is based upon a very simple rule: Divide the horse-power required to be supplied by the number of revolutions that the shaft is to make per minute; multiply the result by 80 and take the cube root of the product, which will give the nominal diameter of the shaft. The actual diameter that such a shaft will be made will be $\frac{1}{16}$ of an inch less than its nominal diameter. This rule does very well for everything except the head shaft, and for the head shaft the constant multiplier should be from 100 to 120, as given in Trautwine's Engineering Pocket-book.

In arranging couplings they should be placed conveniently near to one of the hangers; the head shaft usually rests in two hangers, and if it be in the centre of the line, extension is made from either end of it. Now, in order to know about how far the centre of the coupling will be from the centre of the adjacent hanger, I would advise you to add together the nominal diameter of the two shafts to be coupled, multiply the same by 2 and add to this 3 inches. For example: A 3-inch shaft coupled to a 3-inch shaft will be $(3 + 3) \times 2 + 3 = 15$ inches. If a 3-inch shaft be coupled to a 2-inch shaft, the 3-inch shaft being turned down to the 2-inch size, and a 2-inch coupling used, $(3 + 2) \times 2 + 3 = 13$ inches, which is practically what William Sellers & Co. recommend and express in a table for these distances.

It is quite customary now to make the shafts in double lengths, that is to say, if the bays are only 8 foot span, to make the shaft 16 feet long, using only one-half the number of couplings that would be required if you were to couple at every hanger. I know of no case in which this rule need be deviated from, except the head shaft.

Every line of shaft should have but one set of collars on it to hold the line from moving endwise, and that pair of collars should be on the head shaft or on the shaft of largest diameter. Preferably fixed collars are to be chosen, but some very good loose collars are made at little greater cost with countersunk screws, which answer very good purpose.

In regard to keeping shafting in good order, I do not recommend the use of self-oiling boxes, but think it preferable to have

self-oilers placed above the centre of each box and allow the oil to drip upon the shaft; but it is exceedingly important that oiling should be well attended to, as the friction of the shaft is very much increased if you neglect this precaution.

I cannot help calling your attention to the fact that the most improved style of shafting is, at best, far from being perfect as a mode of transmission. The loss by friction in this kind of transmission is very great, and amounts to as much as from 30 to 50 per cent. of the total power used in establishments where there are many countershafts and many machines to be driven and not mere transmission of power. In the case of William Sellers & Co.'s establishment, where, presumably, the shafting is under the best care possible, this proportion of 45 per cent. to 50 per cent. of power used has continued from the beginning through all the enlargements or extensions that have been required by increasing business. Where buildings connected with one establishment are very much scattered, it will be very well to look for some method of distributing motors to drive the groups of machinery, rather than to carry line shafting continuously from one building to another.

This will be more enlarged upon in my lecture to you on the transmission of power as developed in my visit to Europe in connection with the Cataract Construction Company at Niagara.

With all shafting there are means required to stop and start certain parts independent of the others. For this purpose friction clutches are to be preferred, but in selecting any particular friction clutch I wish you to be careful about the design. I would advise you to use only those that will permit a gradual increase of speed in coupling up to the full speed of the driving shaft. The ordinary male and female cone clutch does not permit this gradual speeding up, and is no better than a positive or tooth clutch. It takes hold when it is capable of driving with full speed. The Hall and Frisbee clutches are examples of true friction clutches, both illustrated in the model room of the Stevens Institute, and there may be other makers that furnish clutches that work as well.

A good friction clutch will not let go when heated by rubbing, or get tighter and drive faster under a slipping motion. For light driving where a high speed of rotation must be obtained by gradual increase of speed, I have seen a clutch made with two or more arms having leather covered ends pivoted to them running inside of the rim of a pulley, the inside being turned plain. The shaft arm drew

these pads away from the surface and so stopped the rotation of the pulley. In starting, the arms were set free, and being hinged to the rotating disks are thrown outwards by centrifugal force against the rim of the pulley and pressed with the force due to centrifugal action against the metal surface, gradually getting up the speed. This centrifugal friction clutch was invented to meet the requirements of centrifugal separators, and was afterwards applied to a traveling crane in the establishment of Rennie Watson, in Glasgow, where I saw it.

OILS USED IN LUBRICATION.—THEIR CHEMICAL REACTIONS AND METHODS OF DETECTION IN MIXTURES.

BY PROF. THOS. B. STILLMAN.

(Continued from page 327, Vol. VIII.)

IODINE ABSORPTION.

THE determination of the iodine absorption of an oil is probably the most important chemical test for recognition quantitatively in a mixture of oils.

Introduced by Hübl (*Ding. Poly. Journ.*, Vol. 253, p. 281), it has since maintained this position, though other chemists have introduced the bromide absorption and others of similar character. They have not been adopted with the confidence of the iodine process.

Warren (*Chem. News*, Vol. 56, p. 188) draws attention to the fact that Chateau in his *Essais Personelles*, p. 70, used the iodine absorption in a manner similar to Hübl many years previously.

The directions for testing oils by this method are given very completely in *Analyse der Fetten Oele und Wachsarten*, Benedikt, p. 74, and in *Oils and Varnishes*, Cameron, p. 248.

In a mixture of two fatty oils with a mineral oil, the best results are obtained by saponifying and separating the fatty acids from the mineral oil. The iodine absorption of the mixed fatty acids is

then taken, and where the nature of them has already been shown by color tests, etc., their proportion can be indicated by the following formula:

$$x = \frac{100\,(I - n)}{m - n}$$

Where x = the percentage of one fat,
y = " " the other,
I = iodine degree of mixture,
m = " " fat x,
n = " " " y.

If more than two fatty oils are present in a mixture with mineral oil, the method of Warren (*Chem. News*, Vol. 62, p. 215; *Jour. Anal. and Applied Chem.*, Vol. 5, p. 215) can be used.

The following determinations of the iodine absorption made in my laboratory are indicative of the variations of the absorption by the different oils:

Prime lard oil	76.4	77.2
No. 1 "	69.8	69.9
XXX "	65.1	65.6
Oleo oil	51.6	51.6
Prime neat's-foot oil	80.1	82.0
Horse oil	82.3	82.5
Natural bow-head whale oil	130.5	131.1
" winter "	121.1	126.0
Extra bleached winter "	124.9	126.1
Bleached spring "	126.1	126.2
Crude sperm oil	82.3	82.3
Prime quality winter white cotton-seed oil.	114.2	114.9
Prime quality summer white cotton-seed oil.	110.2	110.6
" winter yellow " " .	115.9	118.6
" summer " " " .	104.0	104.4
Olive oil	81.	
Herring oil	122.1	123.8
Dog-fish oil	102.7	104.7
Porpoise-head oil	28.9	29.1
Rosin oil, second run	92.1	93.4
" third "	90.4	92.2

References.

E. J. Mills and James Snodgrass (Jour. Soc. Chem. Ind., Vol. 2, p. 435).

L. Archbutt (Jour. Soc. Chem. Ind., Vol. 5, p. 303).

A. H. Allen (Jour. Soc. Chem. Ind., Vol. 5, p. 65).

E. Dieterich (Pharm. Centralhalle, Vol. 8, p. 570).

R. Williams (Chem. Zeit. Rep., Vol. 12, p. 127; Jour. Anal. Chem., Vol. 3, p. 454).

R. H. Thomson and H. Ballantyne (Jour. Soc. Chem. Ind., Vol. 9, p. 588).

R. M. Moore (Jour. Am. Chem. Soc., Vol. 2, p. 155).

T. B. Warren (Chem. News, Vol. 62, p. 27; Jour. Anal. and Applied Chem., Vol. 5, p. 111).

Reuben Haines (Jour. Anal. and Applied Chem., Vol. 5, p. 289).

O. Schweissinger and R. Marzahn (Pharm. Centralhalle, Vol. 28, p. 146).

Benedikt (Ztschr. f. d. Chem. Industrie, 1887, Heft 8).

Stillman (THE STEVENS INDICATOR, Vol. 6, p. 202; Jour. Anal. and Applied Chem., Vol. 3, p. 365).

Bruno Rose (Repert der Anal. Chemie, Vol. 6, p. 685).

F. W. A. Woll (Ztschr. Anal. Chem., Vol. 27, p. 532).

Ch. Dubois and L. Padi (Bull. Soc. Chem. de Paris, Vol. 43, p. 207)

A. Von Asboth (Chem. Zeit., Vol. 14, p. 825).

L. de Koninck (Ned. Tijdschr. von Pharm., 1890, p. 22).

LARD OIL.

Sp. gr., .915; cold test, 7 degrees C.; viscosity at 20 degrees C., 3.6; Maumene's test, 40 degrees C.; iodine absorption, 76.

Adulterants.—Tallow oil, cotton-seed oil, paraffin oil, rosin oil. The best engine oil is a mixture of lard oil and paraffin oil in equal parts. This compound has been in use by the P. R. R. for the past ten years, and after many experiments and trials of different substitutes, still remains the standard.

Passenger car oil is usually a mixture of well oil and lard oil in the proportion of two-thirds well oil and one-third lard oil. Lard oil in the proportion of one part to three of "500-degree well oil" has been found to give the best results as a cylinder lubricator (Dudley, *The Railroad and Engineering Journal*, Vol. 64, pp. 73–126).

NEAT'S-FOOT OIL.

Sp. gr., .915; cold test, 4 degrees C.; viscosity at 20 degrees C. 4; Maumene's test, 40 degrees C.; iodine absorption, 80.

Adulterants.—Same as for lard oil; also cheap grade of olive oil. Schaedler states that light colored whale oils are often used, and poor grades of lard oil.

References.

"The Chemical News," Vol. 42, p. 27.
"Moniteur Scientifique," Quesneville, April, 1880.
"Oils and Varnishes." Cameron, p. 20.
"Handwörterbuch der Tech. Chem." Böttger and Gräger, p. 252.
"The Railroad and Engineering Journal," Vol. 64, p. 73.
"Die Fette Oelen." Dr. George Bornemann, p. 285.

THE MARINE OILS.

References.

"Commercial Products of the Sea." P. L. Simond.
"Animal and Vegetable Fats and Oils." W. T. Brandt.
"The Fish Industries of the United States." E. Brown Goode.
"Spons' Encyclopedia of the Arts and Sciences."
"The Oil, Paint and Drug Reporter."
"Die Technologie der Fette und Oele." W. Carl Schaedler.

"DEGRAS OIL."

The Degras is a product of tanning skins in oil and chemicals, and is practically an emulsion or weak soap, unless the alkali has been set free by weak acid treatment and the moisture boiled out.

The French make is called "Degras," and practically the same class of oil in England goes by the name of "sod oil."

In the United States "wool-grease" is often called "Degras." It, however, contains no fish oil, as does Degras.

In lubrication it is made use of by mixing it with mineral oil in the proportion of 10 per cent. of Degras to 90 per cent. of the mineral oil.

At normal temperature it forms a good lubricant for special purposes, but often froths at high temperatures owing to the water and soap present.

The composition of "Degras" varies greatly as the following analyses by Jean (*Moniteur Scientifique*, Vol. 15, p. 889) show:

	I.	III.
Water	18.90	12.93
Ash	0.25	0.55
Oil	69.71	80.00
Unsaponifiable matter	6.84	....
Resinous substances	4.00	5.81

Consult also—

Benedikt (Untersuchung von Producten der Fett Industrie, p. 157)

Brandt (Animal and Vegetable Fats and Oils).

H. W. Langbeck (Jour. Soc. Chem. Ind, Vol. 10; Jour. Anal. and Applied Chem., Vol. 5, p. 169).

OLIVE OIL.

Sp. gr., .916; cold test, 2 to 6 degrees C.; viscosity at 20 degrees C., 4.2; Maumene's test, 42 degrees C.; iodine absorption of oil, 81.

References.

G. A. Buchheirte (Jour. Soc. Chem. Ind., Vol. 1, p. 32).
M. Seechim (Jour. Soc. Chem. Ind., Vol. 1, p. 237).
T. Leone (Gazz. Chim. ital., 1889, p. 355).
M. Zecchini (Berichte der d. chem. Gesell., Vol. 15, p. 1220).
Souchère (Moniteur Scient., Vol. 2, p. 791).
C. B. Dudley and F. N. Pease (The Railroad and Engineering Journal, Vol. 64, p. 76).
O. Bach (Chem. Zeit., Vol. 7, p. 356; Zeit. fur anal. Chem., Vol. 23, p. 259).
Dr. Geo. Bornemann (Die Fette Oelen, p. 247).
Milliau (Compt. Rend., Vol. 106, p. 530; Jour. Anal. Chem, Vol. 2, p. 200).
H. Levy (Chem. Zeit. Rep., Vol. 12, p. 238).
E. Hirschsohn (Chem. Zeit. Rep., Vol. 12, p. 341).
Legler (Chem. Zeit., Vol. 8, p. 1657).
J. Birl (Archiv der Pharmacie, Vol. 225, p. 310).
A. Andoynaud (Compt. Rend., Vol. 101, p. 752).
E. Bechi (Chem. Zeit., Vol. 2, p. 1328; The Analyst, Vol. 11, p. 171).
L. Archbutt (Jour. Soc. Chem. Ind., Vol. 8, p. 685).
L. A. Bernays (The Manufacture of Olive Oil).

COTTON-SEED OIL.

Sp. gr., .921–.927; cold test, —9 degrees C.; viscosity at 20 degrees C., 3.8; Maumene's test, 75 degrees C.; iodine absorption of oil, 110–118.

References.

B. Nickell (J. Chem. Soc., Vol. 38, p. 925).
J. Macagno (Gazz. Chim., 1881, p. 223).
E. Bechi (Chem. Zeit., Vol. 2, p. 1328).
E. Millau (Mont. Scient., 1888, p. 366).

H. Levy (Chem. Zeit. Rep., Vol. 12, p. 238).
E. Hirschsohn (Chem. Zeit. Rep., Vol. 12, p. 341).
T. Leone (Gazz. Chim. ital., 1889, p. 355).
J. Conroy (Ztschr. für anal. Chem., Vol. 22, p. 289).
Bradford, S. S. (Ztschr. für anal. Chem., Vol. 27, p. 528).
Lavallois (Chem. Zeit., Vol. 2, p. 53).
A. C. J. Charlier (The Engineer, 1890, p. 305).
T. Leone and A. Longi (Gazz. Chim., Vol. 16, p. 393).

The oils made use of in lubrication can be separated into two groups—saponifiable and unsaponifiable. To the former belong all the fatty oils; to the latter the mineral and rosin oils.

The method of Lux (*Zeit. f. anal. Chem.*, Vol. 24, p. 347) is made use of to determine if any fatty oils are present in a mineral oil.

If rosin oil is suspected to have been added to the mineral, it can be identified by the method of Holde (*Mittheil der Konig. tech. Versuchsanstalten*, 1890, p. 19), or the process of E. Valenta (*Zeit. für anal. Chem.*, Vol. 25, p. 441) can be used.

These three tests will indicate, qualitatively, the presence of any fatty or rosin oil in a mineral oil. It is rarely, in the better class of lubricating oils, that more than one oil is added to a mineral oil, such, for instance, as lard oil, or whale oil, in which case saponification easily separates the two oils, and identification of each by special tests can then be made.

When, however, the oil added to the mineral oil itself contains an adulterant, such as lard oil to which cotton-seed oil has been added, then the fatty acids separated by saponification will require a more extended examination to prove the presence of both lard oil and cotton-seed oil.

For the method of saponification and separation of a fatty oil from a mineral oil, consult Benedikt (*Analyse der Fette und Wachsarten*, p. 91).

The following skeleton scheme is given to show the application of the above upon a lubricating oil that qualitative analysis has shown to contain mineral oil, lard oil, cotton-seed oil and rosin oil.

20 gms. of the oil are weighed out in a No. 3 beaker, 100 cc. of an alcoholic solution of potash (80 gms. KHO to 1000 cc. alcohol 98 per cent.) are added, and heat applied with stirring until the alcohol is all driven off; add 100 cc. H_2O, heat with agitation, cool, add 50 cc. of ether, transfer to separatory funnel, stopper, shake well, and allow to stand 6 hours. Draw off the soap solution.

1. *Soap solution* (contains the fatty acids of the lard and cotton-seed oils).

Heat 10 minutes nearly to boiling, cool, acidify with dilute H_2SO_4; allow to stand a few hours; collect the separated fatty acids; determine their weight, then test as follows:

1st portion.—Determine the "melting point." Consult, *Analyse der Fette und Wachsarten*, Benedikt, p. 181.

2d portion.—Determine the "Iodine absorption" and their rates by formula,

$$X = \frac{100\,(I - n)}{m - n}$$

Consult, *Oils and Varnishes*, Cameron, p. 248.

3d portion.—Determine the "Saponification equivalent." Consult, *Oils and Varnishes*, Cameron, p. 246.

These three determinations will give the proportion of fatty acids belonging to the lard oil and to the cotton-seed oil.

Having these, the amount of the oils corresponding to their fatty acids are calculated. Consult, Benedikt, p 138.

(2) *Ether solution* remaining in the separatory funnel is transferred to a flask, the ether distilled, and the mineral and rosin oils weighed together, and then treated by *Twitchell's* process, for the determination of rosin in oils (JOUR. ANAL. AND APPLIED CHEM., Vol. 5, p. 379), or by H. Demski and Th. Morawski's method for the estimation of rosin oil in mineral oils (*Ztschr. f. anal. Chem.*, Vol. 28, p. 2; *Ding. Poly. Jour.*, Vol. 258, p. 82).

Having subtracted the weight of the rosin oil thus found from the weight of the mixture of mineral and rosin oils, the residue is the amount of mineral oil.

References.

Fats and Resins in Lubricants (Chem. News, Vol. 41, p. 36).

Resins and Fatty Oils and Heavy Mineral Oils in Oils of Commerce (Chem. News, Vol. 42, p. 39).

Separation of Hydrocarbon Oils from Fat Oils (Chem. News, Vol. 44, p. 161).

Estimation of Undecomposed Fats in Mixture of Fatty Acids (Chem. News, Vol. 47, p. 72).

Determination of Free Fatty Acids in Oils (Chem. News, Vol. 48, p. 48).

Determination of Cotton-seed Oil in Olive Oil (Chem. News, Vol. 49, p. 49).

Examination of Mineral Oils (Chem. News, Vol. 51, p. 69).

A New Agent for Thickening Mineral Lubricating Oils (Chem. News, Vol. 53, p. 299).

On the Detection of Adulterations in Oils (Chem. News, Vol. 53, p. 292).

Determination of Mineral Oils (Chem. News, Vol. 57, p. 81).

Blown Oil (Chem. News, Vol. 58, p. 170).

New Method of Examining Mixture of Lard and Olive Oils (Chem. News, Vol. 58, p. 15).

Process for Proving Rosin Oil (Ding. Poly. Jour., Vol. 258, p. 94).

Foeke's Method for Mineral Oils and Fats (Ding. Poly. Jour., Vol. 259, p. 146).

Examination of Mineral Lubricating Oils for Other Oils (Ding. Poly. Jour., Vol. 236, p. 487).

Estimation of Rosin in Oils and Fats (Ber. d. deut. Chem. Gesell., Vol. 15, p. 965).

Blown Oils, from Cotton-seed Oil, Cotton Oil, Rübol (Ztschr. für anal. Chem., Vol. 27, p. 528).

Melting Points of Fatty Acids of Olive Oil, Cotton-seed Oil., etc. (Gazz. Chem., Vol. 16).

Estimation of Rosin Oil in Mineral Oils (Ding. Poly. Jour., Vol. 258, p. 82).

Estimation of Cotton-seed Oil in Lard (Ztschr. für Angew. Chem., 1889, p. 119).

The Detection of Rosin Oil in Castor Oil (Jour. Soc. Chem. Ind., Vol. 10).

Detection of Cotton-seed Oil in Lard (Chem. Zeit., Vol. 14, p. 93).

Examination of Olive Oil (Chem. Zeit., Vol. 14, p. 1,202).

Determination of Mineral Oils in Fatty Oils (Zeit. für. Angew. Chem., 1890, p. 261).

Determination of Mineral Oils in Fatty Oils (Jour. Soc. Chem. Ind., Vol. 9, p. 696).

Adulteration of Oils. Lard Oil with Cocoanut Oil., etc. (Amer. Chem. Jour., 1886).

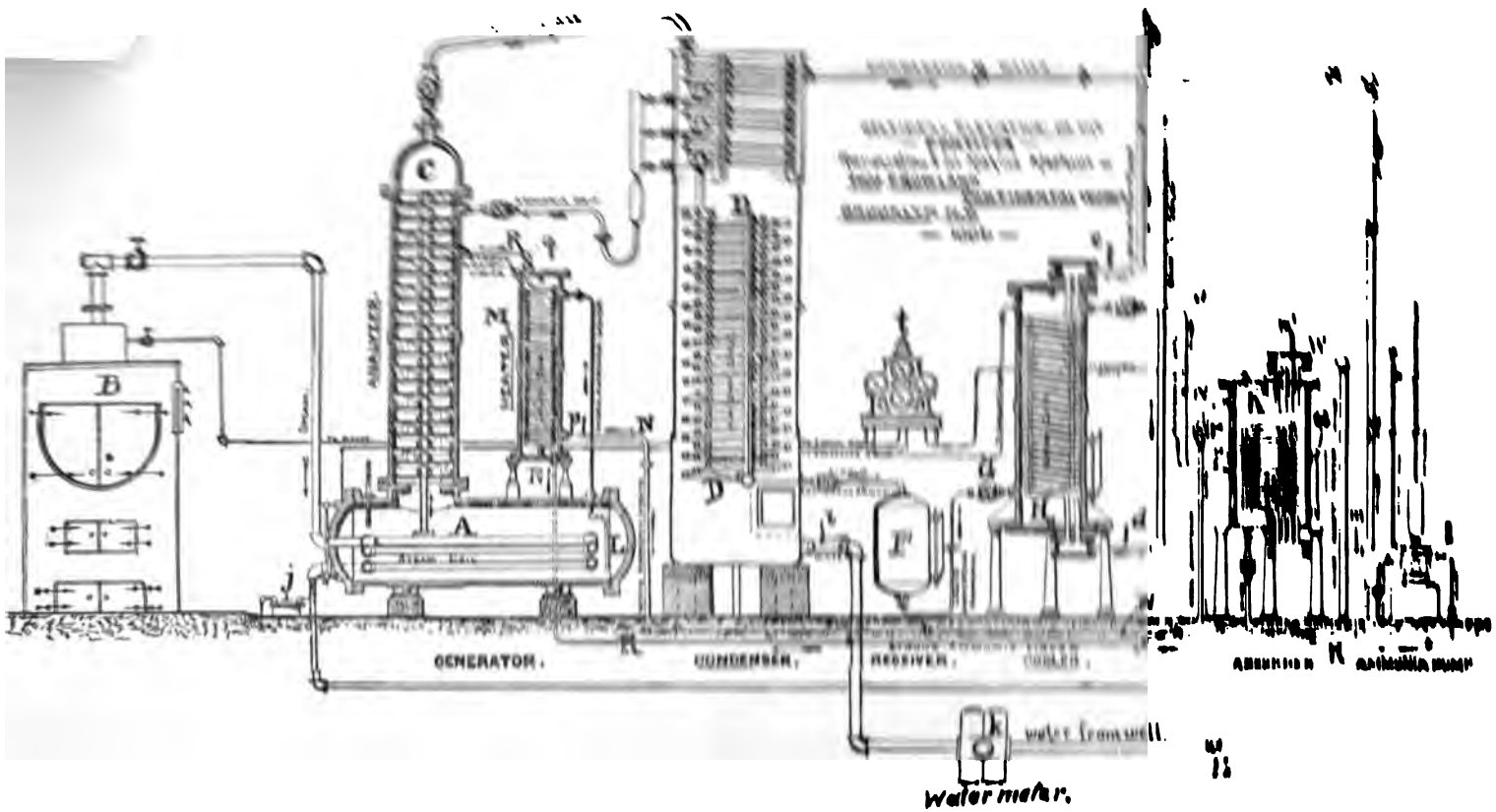
Testing and Reporting upon Lubricating Oils (Chem. News, Vol. 55, p. 203).

The Examination of Lubricating Oils (THE STEVENS INDICATOR, Vol. 7, p. 211).

ON THE HEAT OF DISSOCIATION OF AMMONIA IN REFRIGERATING MACHINES, OF THE ABSORPTION TYPE.

BY PROFS. J. E. DENTON AND D. S. JACOBUS.

A SATISFACTORY theory of the absorption machine is to be found in Ledoux's essay (on refrigerating machines) which first appeared in *Annales des Mines*, 1878, and subsequently was translated in its text for Van Nostrand's *Science Series*. In the course of preparing a new edition of this Science Series Issue, the writers have attempted to determine to what extent the various constants involved in this thermo-dynamic theory may be in error, by applying the latter, with the constants as given by Ledoux, to experimental meas-


B
C
A
L
N
D
F
GENERATOR.
CONDENSER.
RECEIVER.
water from well.
Water meter.

urements of performance. In the case of the absorption machine, the most important constant which has not been the subject of independent experimental determination, is the heat of dissociation for hydrate of ammonia at high pressure. It has been determined for low pressure, by Favre and Silberman, to be 926 B.T.U. per pound of ammonia dissociated from, or absorbed by, water. The conclusions reached are as follows: If the heat of dissociation does not practically vary with pressure, as is stated by Ledoux, then in order for the thermodynamic theory to account for the best performance recorded for an absorption refrigerating machine, it is necessary to make either of the following two assumptions: *1st*, that 13 per cent. of the weight of anhydrous ammonia circulated is entrained water, when the gas leaves the generator for the condenser, and that 8 per cent. of this 13 per cent. returns to the generator from the drip coils at the top of the condenser, (see Fig.)—while the remaining 5 per cent. circulates through the refrigerating coils mixed with the anhydrous ammonia; or, *2nd*, that 23 per cent. of water is entrained with the gas and accompanies the latter into the condenser, but is all returned as "drip liquor" to the generator, so that only anhydrous ammonia circulates throughout the cooler and absorber.

The object of the present article is to give in detail the steps which lead to these conclusions. It is also shown that an increase of the heat of dissociation from 926 to 1,058 units is equivalent to making the drip liquor 10 per cent. instead of 22 per cent., with no moisture carried throughout the system.

The economy is the same for all the above sets of conditions.

Experiments with absorption machines in which the amount of water in the ammonia leaving the generator and present in the cooler shall be determined, are necessary to settle which of the above conditions represents the actual cycle of absorption machines.

The data upon which all calculations rest are from a 35-ton absorption machine, whose performance was reported in the Erie

meeting of the American Society of Mechanical Engineers. [See paper No. 350, Transactions, Vol. X.]

For the particular figures in that paper we have substituted those of a 10 hour test, which give nearly the same results as regards economy and capacity, but are more reliable in the range of temperature for the condenser and absorber, and the amount of condensing water. These quantities were both determined by averaging readings of thermometer and water meter, taken every 15 minutes during 10 hours, whereas in the case of the figures reported to the Mechanical Engineers, the water was, as explained in the paper, in a meaure estimated. Also, the temperature range in the condenser and absorber was the average of only a few readings, as the behavior of the absorber was not a special object of the investigation, the latter being mainly directed toward determining the average refrigerating effect throughout seven consecutive days.

The data used herein is given in Table I.; Table II. gives the distribution of heat which the calculations show to be necessary in order to account, by the theory, for the result obtained by experiment.

If it is true, as is most probable, that the heat of dissociation in the generator is practically the same as the heat of absorption in the absorber, then the economy of an absorption machine for the production of very low temperatures is considerably superior to that of a compression machine operated by a first-class non-condensing engine, even with the amount of moisture assumed in our calculations. Should, however, an absorption machine make pure anhydrous ammonia, and exhaust the steam of its ammonia circulating pump into the generator, and have its interchanger so proportioned that the 19.7 per cent. waste shown in Table II. is avoided, then comparison of columns 7 and 8, of Table III., shows that for the production of low temperatures an absorption machine can have a superior economy to a compression machine, even when the latter is operated by a compound engine, using as little as 14 pounds of steam per hour per horse power.

TABLE I.

TEST OF 35 TON PONTIFEX REFRIGERATING MACHINE AT PACKING HOUSE OF SPERRY AND BARNES, NEW HAVEN:

Average pressures in lbs. per sq in. above the atmosphere.	Generator	137.6
	Steam: Boiler	80.0
	Steam: Generator	45.0
	Cooler	25.7
	Absorber	22.9
Average temperature in Deg. Fahrenheit.	Generator	255
	Brine Inlet	20.7
	Brine Outlet	15.73
	Condenser Inlet	56.0
	Condenser Outlet	77.5
	Absorber Inlet	77.5
	Absorber Outlet	110.00
Average range of Temperature in Deg. Fahrenheit.	Condenser	21.5
	Absorber	32.5
	Brine	4.97
Brine circulated per hour in cu. ft.		1701.3
Weight of brine circulated per hour in lbs.		124195
Specific heat of brine		.81
B. T. U. eliminated per lb. of brine		4.026
Total *B. T. U.* eliminated in brine per hour		500010.
Steam condensed per hour to volatilize ammonia in pounds		1,614
Steam to operate ammonia pump in pounds		316
Circulating water per hour in pounds	Observed	36,000
	Calculated	36,270
Heat abstracted in circulating water per hour in *B. T. U.*	From condenser	774,000
	From absorber	1,170,000
Ice melting capacity in 24 hours, in tons		42.2

Ice melting capacity in pounds per pound of coal assuming that 10,000 *B. T. U.* are imparted to the boiler per pound of coal, or that the evaporation is 10.35 pounds per pound of coal from and at 212° Fahr.*

Not including steam required to run the ammonia pump.

$$= \frac{500{,}010 \times 10{,}000}{1{,}614 \times 142.2 \times 908} = 24$$

Including steam required to run the ammonia pump.

$$= \frac{500{,}010 \times 10{,}000}{1{,}930 \times 142.2 \times 908} = 20.1$$

Ice melting capacity in pounds per pound of coal, assuming a rate of evaporation of 10 pounds per pound of coal—including steam required to run the ammonia pump

$$= \frac{500{,}010 \times 10}{1{,}930 \times 142.2} = \ldots\ 18.2$$

*With Cumberland coal, having 7 per cent. of ash, this would be equivalent to an evaporation of 11.1 lbs. of water per pound of combustible from and at 212° Fahr., which figure is readily obtained in the best class of boilers. The figure 908, employed in the calculation, is the latent heat of steam at 45 pounds pressure.

BALANCE OF THE QUANTITIES OF HEAT IMPARTED TO AND GIVEN OUT BY THE MACHINE.

Total heat imparted to the condensing water per hour and amount lost by radiation, in *B. T. U.*	1,944,460
Total heat imparted to the machine by the steam at the generator, and by the brine, in *B. T. U.*	1,965,510
Amount not accounted for, in *B. T. U.*	21,050
Discrepancy in per cent	1.1

TABLE II.

COMPARISON OF THE ECONOMY ACTUALLY OBTAINED WITH THE RESULTS CALCULATED BY MEANS OF LEDOUX'S EQUATIONS.

Ice melting capacity per pound of coal, obtained by test, assuming that each pound of coal imparts 10,000 *B. T. U.* to the boiler	20.1 lbs
Ice melting capacity per pound of coal, by Ledoux's equations, assuming a perfect heater action, no drip liquor, no water carried over by the ammonia, and no losses by radiation.*	38.5 lbs

The calculated losses in per cent. of the amount of heat imparted to the boiler, or 1,465,500 × 1,930 ÷ 1,614 = 1,752,400 *B. T. U.* per hour, are : †

Heater	19.7%
Drip liquor	3.9%
5% water entrained with the ammonia	16.7%
Ammonia circulating pump	16.4%
Radiation	.9%
	57.6%
There is a gain in refrigerating capacity in the machine tested, due to superheating the ammonia in the cooler, which is equivalent to	9.9%
Net Loss	47.7%

Equivalent of losses in ice melting capacity = 38.5 × .477 = 18.4 lbs
Theoretical useful ice melting capacity = 38.5 — 18.4 = 20.1 lbs

* The conditions substituted in Ledoux's equations are: Temperature of condenser, 80° Fahr. Temperature of cooler, 13° Fahr. Temperature of absorber, 130° Fahr.

† The per cents. of loss, with the exception of that due to the 5 per cent. of water entrained with the ammonia, are found by dividing the heat expended, as shown in the text, by the total heat supplied to the boiler. The loss due to 5 per cent. of entrained water is found by comparing the efficiency of the machine when working with 5 per cent. of entrained water, with that obtained when no water is carried over with the ammonia. The latter calculations are given in the revised work of Ledoux on Ice Making Machines, now passing through the press.

TABLE III.

Relative Performance of Ammonia Compression and Absorption Machines, assuming no water to be entrained with the Ammonia Gas in the Condenser.

It is assumed in the calculations for both the absorption and compression machines, that 1 pound of coal imparts 10,000 B. T. U. to the boiler. This is equivalent to an evaporation of about 8¾ pounds of water per pound of coal from a feed water temperature of 70° Fahr., and a pressure of 90 pounds per square inch above the atmosphere. The condensed steam from the generator of the absorption machine is assumed to be returned to the boiler at the temperature of the steam entering the generator. The engine of the compression machine is assumed to exhaust through a feed water heater that heats the feed water to 212° Fahr. The engine is assumed to consume 26¼ pounds of water per hour per horse-power. The figures for the compression machine include the effect of friction, which is taken at 15 per cent. of the net work of compression.

Number of Comparison.	Condenser.		Refrigerating Coils.		Temp. of Absorber in Degs. Fahr.	Pounds of Ice Melting Capacity per Pound of Coal.				British Thermal Units per Pound of Ammonia Circulated through the System.										Quantities of heat, in per cent. of amount furnished to the Boiler, lost in Exhaust Compression of Machine and by Friction.	
						Compressing Machine.		Absorption* Machine.			Heat Furnished to Boiler.							Heat Wasted in Exhaust of Compression Mach'e & by Friction			
	Temp. in Degs. Fahr.	Absolute Pressure in Lbs. per Square Inch.	Temp. in Degs. Fahr.	Absolute Pressure in lbs. per Square Inch.		Using 3 lbs. of Coal per Hour per H. P.	Using 1.6 lbs of Coal per Hour per H. P.	Absorption Machine in which the Ammonia Circulating Pump Exhausts into the Generator.	Absorption Machine in which the Ammonia Circulating Pump Exhausts into the Atmosphere through a Heater, yielding 212° Temp. to the feed water	Heat Furnished to Generator of Absorption Machine.	Compression Machine Using 3 lbs. of Coal per Hour per H. P.	Absorption Machine in which the Ammonia Circulating Pump Exhausts into the Generator	Absorption Machine in which the Ammonia Circulating Pump Exhausts into the Atmosphere through a Heater.	Refrigerating Effect. (Same for Both Systems.)	Heat Abstracted from Condenser. (Same or Both Systems	Equivalent of Work of Compres'n. (Same for Both Systems.)	Abstracted from Absorbe of Absorption Machine	Using 3 lbs. of Coal per Hour per H. P.	Using 1.6 lbs. of Coal per Hour per H. P.	Using 3 lbs. of Coal per Hour per H.P.	Using 1.6 lbs. of Coal per Hour per H. P.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	61.2	110.6	5	33.7	61.2	38.1	71.4	38.1	33.5	969	969	969	1,100	524	596	72	897	897	445	92.6	86.1
2	59.0	106.0	5	33.7	59.0	39.8	74.6	38.3	33.9	967	929	967	1,090	526	595	69	898	860	426	92.6	86.1
3	59.0	106.0	5	33.7	130.0	39.8	74.6	39 8	35.1	931	929	931	1,054	526	595	69	862	860	426	92.6	86.1
4	59.0	106.0	—22	16.9	59.0	23.4	43.9	36.3	31.5	1,000	1,550	1 000	1,151	516	631	115	885	1.435	711	92.6	86.1
5	86.0	170.8	5	33.7	86.0	25.0	46.9	35.4	28.6	988	1,399	988	1,221	497	601	104	884	1,295	642	92.6	86.1
6	86.0	170.8	5	33.7	130.0	25.0	67.9	36.2	29.2	966	1,399	966	1,199	497	601	104	862	1,295	642	92.6	86.1
7	86.0	170.8	—22	16.9	86.0	16.5	30.8	33.3	26.5	1,025	2,077	1,025	1,287	486	640	154	871	1,923	953	92.6	86.1
8	86.0	170.8	—22	16.9	130.0	16.5	63.9	34.1	27.0	1,002	2,077	1,002	1,264	486	640	154	848	1,923	953	92.6	86.1
9	104.0	227.7	5	33.7	104.0	19.6	36.8	33.4	25.1	1,002	1,707	1,002	1,332	476	603	127	875	1,580	786	92.6	86.1
10	104.0	227.7	—22	16.9	104.0	13.5	25.8	31.4	23.4	1,041	2,421	1,041	1,399	466	646	180	861	2 241	1,116	92.6	86.1

* 5 per cent. of water entrained in the ammonia will lower the economy of the absorption machine about 15 to 20 per cent. below the figures given in the table.

BALANCE OF THE QUANTITIES OF HEAT IMPARTED TO AND GIVEN OUT BY THE MACHINES.

The sum of the quantities of heat imparted to the generator and to the brine will be equal to the amount carried away at the condenser and absorber, plus the heat lost by the radiation of the entire machine.

Generator.—The steam employed to heat the generator parts with its latent heat only, for the water condensed from it is drawn off by means of a Nason trap, so that it is practically at the temperature of the steam.

The steam is about dry on entering the generator, for the calculated amount of radiation from the pipe leading from the boiler to the generator counteracts the superheating effect produced by throttling from 80 to 45 pounds pressure. We therefore have for the heat imparted to the generator, $1{,}614 \times 908 = 1{,}465{,}500$ B. T. U.

Cooler.—The weight of brine circulated per hour is 124,195 pounds. The range of temperature is 4.97 degrees, which, multiplied by the specific heat of the brine, or .81, gives $4.97 \times .81 = 4.026$ *B. T. U.* eliminated per hour per pound of brine.

The total amount eliminated per hour is, therefore, $124{,}195 \times 4.026 = 500{,}010$ B. T. U.

Condenser.—The weight of water circulated through the condenser per hour is 36,000 pounds, and the range of temperature is 21.5° Fahr. The heat imparted to the condensing water is therefore, $36{,}000 \times 21.5 = 774{,}000$ B. T. U.

Absorber.—The weight of water is the same as for the condenser and the range of temperature is 32.5° Fahr. The heat imparted to the water is, therefore, $36{,}000 \times 32.5 = 1{,}170{,}000$ B. T. U.

Losses by Radiation.—The generator is covered with hair-felt and lagged with wood. The surface is about 200 square feet. Taking the rate of radiation at ¼ B. T. U.* per hour, per square foot,

* This is the minimum value determined by Prof. J. M. Ordway, for hair-felt coverings. Trans. A. S. M. E. Vol. V., p. 37.

per degree of difference of temperature between the air and the interior of the generator, we have—

$$200 \times \tfrac{1}{4} \times (235—80) = 7{,}750 \text{ B. T. U.}$$

235 degrees is about the average temperature of the generator, including the analyzer and heater.

Heat will be imparted to the cooler so that, considering it as a radiation effect, the value will be minus.

The surface of the cooler is 124 square feet and its average interior temperature is 18 degrees. It is covered in the same way as the generator, so that the radiation is ¼ B. T. U. per hour per degree of difference of temperature.

Hence the radiation per hour is—

$$124 \times \tfrac{1}{4} \times (80-18) = 1{,}922 \text{ B. T. U.}$$

The surface of the condenser is about 300 square feet. This is not covered so that the rate of radiation will be about 2 B. T. U.* per square foot of radiating surface, per degree Fahr. difference of temperature per hour. Hence the radiation per hour is—

$$300 \times 2 \times (80-67) = 7{,}800 \text{ B. T. U.}$$

The surface of the absorber is about 87 square feet and its average interior temperature 94° Fahr. This is not covered, so that the radiation per hour will be—

$$87 \times 2 \times (94-80) = 2{,}436 \text{ B. T. U.}$$

The various losses are, therefore, as follows :

Generator,	7,750 B. T. U.	Cooler,	1,922 B. T. U.
Absorber,	2,436 "	Condenser,	7,800 "
	10,186 "		9,722 "

The total radiation per hour is, therefore,—

$$10{,}186 - 9{,}722 = 464 \text{ B. T. U.}$$

* Tredgold's experiments. D. K. Clark's Manual, p. 472.

SUMMATION OF HEAT QUANTITIES.

Heat imparted to generator, per hour	1,465,500	B. T. U.
" " " brine " "	500,010	" " "
Sum	1,965,510	" " "
Heat from condenser, per hour	774,000	" " "
" " absorber " "	1,170,000	" " "
" by radiation, per hour	464	" " "
Sum	1,944,460	" " "
Amount not accounted for	21,050	" " "
Discrepancy in per cent. of total heat imparted	1.1	

(TO BE CONTINUED.)

NOTES ON ELECTRO-MAGNETIC TRANSMISSION OF ENERGY.*

BY WM. S. ALDRICH, M. E., '84.

Early Definitions and Classifications of Mechanism were (1) from the purely kinematical standpoint, with regard to the motions of any particular combination; and (2) from the purely mechanical standpoint, with respect to the means by which motion could be transferred. Examining for a moment the kinematics of mechanisms, we find that Monge (1806), speaks of mechanisms as means for altering the direction of motion, without any special reference to the magnitude of such alterations or changes in motion, or to the velocity-ratio communicated from one moving body, or point of a body, to another moving body or point. On this idea he based his arrangement of mechanisms according to the possible combinations of the four principal kinds of motion: continuous and reciprocating rectilinear, and continuous and reciprocating circular

* Abstract of paper presented to the Electric Club of the Johns Hopkins University, November 9, 1891.

motions. Change of motion thus becomes the leading element in the study of mechanisms; each particular combination that has thus far come into existence or been invented, is studied of and by itself. The method might well be adapted for historical study, but not for the comparative study of the development of the science of mechanism, much less for its future in the invention of new combinations. Borgnis (1818), introduced another leading idea, which has received more than its share of importance, because so easy of application and so externally evident to the most casual observer. He divided the mechanisms of transmission machinery into: (*a*) parts generating energy, as prime movers; (*b*) parts transmitting the energy, as intermediate connecting mechanism; (*c*) parts receiving the energy, as the working parts, machine tools, and like mechanical combinations, arranged to turn the transmitted energy to useful account.

The Science of Pure Mechanism received a great impulse by the structure which Willis built upon the fundamental notions of Monge and Ampère. Only those mechanisms were considered pure mechanisms by Ampère (1830), which consisted entirely of rigid bodies, thus raising to a prominent point the means by which motion was produced or transferred; and his definition of a machine is given as "an instrument by the help of which the direction and velocity of a given motion can be altered." Willis' earlier classification (1841), is primarily based upon the elements of comparative motion,—directional-relation and velocity-ratio, either or both of which may be constant or variable, according to the conditions imposed upon the mechanism; the means or mode of connection were subordinate, and carefully excluded anything but connection by rigid bodies. Weisbach usually followed the continental methods of Lanz and Monge. Rankine developed the plan of Willis, but reversed his fundamental divisions,—a method which Willis himself later adopted, in his second classification of mechanisms (1871), as his experience in developing the science of mechanism had shown it to be the more helpful method of the two. The methods of studying what had been done were still almost entirely algebraic and geometric, with scarcely any intimation of what might be done in the way of a further extension of the boundary lines of even pure mechanism. As Rankine made the mode of communicating the motion fundamental, he included *hydraulic connection* among the several modes of connection already given by Willis. This introduction of fluid connection into the science of mechanism marks a distinct ad-

vance, and one to which we shall have occasion to refer more particularly. The fluid connection, discarded by Ampère and Willis, was introduced by Giulio (1847), and Laboulaye (1849).

The Kinematics of Machinery, as developed by Reuleaux (1874), marked a decided advance above all former methods of treating mechanisms and machines, in not only laying down a scientific basis for the analysis of existing combinations, but also indicating the probable lines of development to be followed in kinematic synthesis and the designing of mechanisms. A mechanism is defined to be "a closed kinematic chain, which is compound or simple, and consists of pairs of elements ; these carry the envelopes for the motion which the parts in contact must be given; and by these envelopes all other motions are prevented." A mechanism so operated as to do work, constitutes a machine, which is a "combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work, accompanied by certain determinate motions," and fluid connection has a legitimate place among mechanical or rigid connecting links. For the means used to communicate the motion may be quite different, but the kinematic question remains ever the same, which is that of pure motion, whether as undergoing change or alteration (Monge), or as comparative motion (Willis, Rankine), or as constrained motion (Reuleaux). And along with this we have the dynamic or kinetic question, dealing with the energy transmitted by and through the mechanism in its operation as a machine, which brings us more nearly face to face with the medium for the transmission of energy. The mechanical, hydraulic, pneumatic, and electric transmission of energy have become well established methods, with corresponding mechanisms, machines and machinery. And a later generalization places electro-magnetic mechanisms side by side with the older science of pure mechanism.

Electro-Magnetic Mechanisms have been defined by Sylvanus P. Thompson,* along certain broad lines in which it is apparent that we have power, transmitted electrically along a wire, made to do work and produce mechanical motions in a given electro-magnetic combination. The "modern views" of electrical and electro-magnetic action lead us to consider the luminiferous ether to be the real

**Electrical World*, 1891—Jan. 17–24, Feb. 21; also, "The Electro-Magnet and Electro-Magnetic Mechanisms" (Spon).

medium by and through which the energy is transmitted; and, that the wire of the coil or line, as well as the magnetic body (as iron) forming the core of the magnet, are both simply centralizing agents, which concentrate (as it were) the energy of the ether medium, and enable us to transmit and utilize this energy in almost an inconceivable variety of ways. The ether medium, as a mode of connection and of communicating motion, has thus a legitimate place along with hydraulic and pneumatic connections. And the study of the mechanism of the ether medium carries us far out along the present confines of modern investigation.

Electro-Magnetic Transmission of Energy is here understood to be the more direct, immediate, or short-distance transmission of energy implied in handling the magnetic circuit, in very much the same way that the electric circuit has already been utilized for long-distance [telelectric]* transmission of energy. This method of transmitting energy has its peculiar mechanisms, machines, and machinery, characteristic of the medium employed. The machine problem practically underlies all methods of transforming motion and transmitting energy. For it is always possible to develop any one of these several methods with a machine basis, as a material embodiment. The ether medium is ideal in one respect, for by its means we can transfer motion and transmit energy without contact of the elements directly concerned in the circuit of the medium, or in its own cycle of operations. In other cases, there is contact of the elements of the magnetic circuit. We have thus pure, or direct transmission of energy, by the ether medium; and, indirect, or mixed transmission, in which mechanical forces and material contact of elements are induced and modified to any desirable extent, by the real electro-magnetic stresses and strains in the ether medium.

Direct and Indirect Electro-Magnetic Mechanisms are seen in their essential differences in practical applications in the following: (1) direct transmission, simply by and through the electro-magnetic stresses in the ether medium, as in the eight-pole multipolar motor (or dynamo) used as an electro-magnetic clutch in the mechanism of the MacQuesten electric car gearing; † (2) indirect

*Telodynamic, for long-distance transmission of energy by mechanical means, as by wire ropes. Telelectric, for similar long-distance transmission of energy, but by electrical means.

† *Electrical World*, 1890, June 14, p. 402.

transmission, by and through an electro-magnetically actuated mechanism, as in the Wynne & Raworth electro-magnetic clutch,* classified by Sylvanus P. Thompson as a "polarized mechanism," consisting in reality of a very simple but effective form of friction clutch, in which the friction is brought about by the surface contact of the electro-magnet core and its disk armature, but which might be operated or actuated to equal advantage by another means, such as hydraulic, pneumatic or steam pressure, or by hand, as a hand brake. It is somewhat important to note these distinctions, not necessarily as forming any definite basis for the identification and classification of electro-magnetic machinery, but to aid in the clear understanding of the operations of the medium employed and its own peculiar cycle. The ordinary brake shoes of a car may be operated (in some cases to almost equal advantage) by simple mechanical means, in the application of power through a system of levers, or other power reduplication and multiplying mechanism, actuated by: (1) compressed air, or (2) by steam pressure, or (3) by hydraulic pressure, or (4) by electro-magnetic means, or (5) even by hand pressure, within certain limits of safety. The mechanics of this brake problem remain the same, involving the statics and dynamics of the medium and its mechanism, and the kinematics of the moving elements. The machine design, as a problem in the mechanics and strength of materials, remains practically the same, as determined by the impressed, transmitted and applied forces. The main element—that of the friction of the surface contact of the brake shoe and the wheel—is absolutely independent of the way of applying the force, depending upon the intensity of that applied force and the character of the surfaces in contact. In a few instances, the way the force is applied to the brake shoe may slightly modify the intervening mechanism and the disposition and proportion of its parts for the particular case in hand. However inconvenient, not to say impracticable, it may be to oppose steam pressure to steam pressure, air pressure to air pressure, or hydraulic pressure to hydraulic pressure, in such a simple (but typical) combination as the car brake mechanism, it is altogether possible, and may even be desirable (in special cases), to oppose the electro-magnetic stresses of the ether medium, as we have seen is the case of the MacQuesten electric car gearing and

* *Electrical World*, 1891, February 21, p. 136.

clutching device. So that these distinctions between direct and indirect transmission have little, if any, practical value till we come to the electro-magnetic transmission of energy by and through the stresses and strains of the ether medium.

The Cycle of Operations of Electro-Magnetic Machinery may be viewed and defined from the kinematic, dynamic or energetic* standpoint. The cycle of the ether medium—its magnetic-flux cycle of stress—has been briefly outlined by Sylvanus P. Thompson.† Though possessing some characteristic features of the thermo-dynamic cycle by the steam-engine considered as a heat-engine, yet there are inherent and fundamental differences. In some electro-magnetic mechanisms there is a periodic rise and fall, from zero to a maximum, or from a minimum to a maximum; while, in others there is simply an incompleted cycle—a kind of stress diagram of the ether medium. Such stress diagrams have been quite fully plotted for certain magnetic bodies, as curves of permeability.

[It remains to be seen whether any relation exists between the mechanical stress diagrams for magnetic bodies and the ether stress diagrams of the same bodies; that is, between the molecular stress diagrams and the stress diagrams of the ether medium environing the molecular constitution of the magnetic body. Each typical stress diagram has its peculiar "elastic limit" point, or point of saturation, which sets a limit to the extent to which the body may be subjected in practice to these stresses.]

Dynamotors for the Electro-Magnetic Transmission of Energy have been developed from typical forms of moto-dynamos for the transformation of continuous or direct currents of electricity.‡ In the latter case electrical energy is supplied and electrical energy is the output. In the former, the reverse is the case,—mechanical energy or power is supplied and is also the output, having made the desired transformation within the mechanism of the dynamotor. The simplest form of dynamotor is that of two armatures in the same magnetic circuit. Mechanical power supplied to one armature, as a dynamo, generates current, which drives

* See Thurston's "Manual of the Steam-Engine," Part I., pp. 298, 304.

† *Electrical World*, 1891, Jan. 24, p. 63.

‡ Lahmeyer's system—*Electrical World*, 1889, Oct. 12; 1891, June 20. Elihu Thomson's system—*Electrical World*, 1887, April 16. Bernstein's system—*Electrical World*, 1890, Jan. 25.

the other armature in the same magnetic circuit as a motor. These two armatures may be at any angle with respect to each other, and have any velocity-ratio of rotation, and turn in the same or in opposite directions. The velocity-ratio may be maintained uniform or made variable at will, increasing or decreasing to any desired amount. The directional-relation may be constant or variable (Willis), along with constant or variable velocity-ratios. We have, therefore, a species of electro-magnetic mechanism which is kinematically equivalent to any one of the many mechanical combinations now employed in the transmission of energy and the conversion of circular motion: such as spur and bevel gear wheels, screw, worm and skew-bevel gear wheels, belted connections of all kinds, friction wheel combinations, and parallel-rod linkages for equal rotations. And the ability to place the armature shafts of the dynamotor in any required way with respect to each other (within the limits of the same magnetic circuit) gives rise to forms kinematically equivalent to Oldham's coupling and Hooker's Universal joint, with the desirable exception that there are no periodic fluctuations in the velocity-ratios. Three or more armatures may be combined in the same magnetic circuit, in almost any desirable way, as, for instance, in multiple drills. The continuous or alternating current may be employed—very probably the latter, in a modified form, especially adapted to dynamotor electro-magnetic transmission of energy.* For special forms of electro-magnetic machinery, with axes oblique and non-intersecting, mitis-metal fields may be used. The efficiency of transformation should approach that of a similar form used as a motor-dynamo, which has been put as high as 92 per cent.† A great many mechanical conditions will enter to lower even this efficiency of transformation; but, with well designed dynamotors, the efficiency should greatly exceed that of the present means of transmitting energy by belts and gear wheels. The cost at present is prohibitive of any extended introduction of electro-magnetic transmission of energy. But this will be lowered, it is hoped, by improved methods of designing and manufacturing electro-magnetic machinery.

Electro-Magnetic Epicyclic Mechanisms have also been derived, by which an armature continuously revolving in one direction may,

* "Notes on Electro-Magnetic Machinery," presented before the Electrical Section of the Franklin Institute, December 1, 1891.

† Lahmeyer System, *Electrical World*, 1891, June 20, p. 463.

through the intervention of electro-magnetic mechanism, cause any desired rotation to the arm of an epicyclic train of mechanism. The epicyclic train may consist entirely of electro-magnetic elements or be a mixed mechanism, consisting of a mechanical epicyclic train of mechanism more or less actuated or controlled by electro-magnetic means. [The arm of the epicyclic train may, as in the mechanical combination, have one or both of its kinematic elements constant or variable: that is, one or both mechanisms of the epicyclic train may be variable, whereas the most ordinary gear-wheel epicyclic train has the velocity-ratio of its elements fixed or constant. Thus, by electro-magnetic, as well as by purely mechanical means, it is possible* to devise a variable speed epicyclic mechanism.]

Electro-Magnetic Conversion of Motion along with the electro-magnetic transmisson of energy, is exemplified in the Van Depoele electro-magnetic reciprocating drill.† The combination in this mechanism of a pulsating (constant-direction and variable-intensity) current, with an alternating (alternating-direction and variable-intensity) current, make it possible to electro-magnetically control a reciprocating movement from a continuous rotary motion. [There are many varieties of this conversion of uniform rotary motion into a reciprocating rectilinear motion, by means of solenoidal plungers, several of which may be seen in the Van Depoele patents: No. 422,855, March 4, 1890; No. 451,786, May 5, 1891; No. 458,873, September 1, 1891; No. 458,954, September 1, 1891; No. 461,294, October 13, 1891: No. 461,295, October 13, 1891.]

* Notes on Electro-Magnetic Machinery (second paper), presented before the Electrical Section of the Franklin Institute, January 5, 1892.

† *The Electrician* (London), November 6, 1891.

ECONOMY OF PAWTUCKET PUMPING ENGINE, WITH AND WITHOUT SUPERHEATING.*

BY PROF. D. S. JACOBUS.

AFTER examining the tests made on the Pawtucket engine, including those made by Mr. Kent, Mr. Donkin of the Committee on Steam Jackets of the British Association of Mechanical Engineers expressed the opinion that the small effect of the jackets may be due to the fact that the steam entering the engine is slightly superheated. The same idea has been suggested by Mr. Kent and Mr. Barrus. Mr. Nagle also, at a previous meeting,† advanced the decided opinion that the superheating is the cause of the small effect of the jackets.

It being desired on the part of Prof. Denton and myself that no open question be left regarding the performance of this remarkable engine, Prof. Denton arranged to have an additional test made with steam containing a small percentage of moisture, and the privilege of making these measurements was accepted by the speaker. The results are now reported as follows :

On November 6th the engine was tested for eight hours without jackets in use, and with steam superheated 17° Fahr., two feet from the cylinder. The results gave 14.16 pounds per hour per horse power, which is 0.8 per cent. lower than Mr. Kent's test, under similar conditions, but with only 11 degrees of superheating.

A portion of the steam pipe between the boiler and the engine, about 15 feet long, was then stripped of the non-conduction covering. The extra radiation from the pipe, thus permitted, reduced the superheating to about 5° Fahr., but as it was desirable to destroy all superheating, water from the boilers was injected into the steam pipe in such an amount as to accomplish this and produce a small degree of wetness. The exact amount was not determined, but from what follows it is fair to conclude that the moisture averaged at least 0.1 per cent. The engine was then again tested

* Discussion of paper by Mr. Kent on Influence of Steam Jackets of the Pawtucket Pumping Engine, presented at New York meeting of the American Society of Mechanical Engineers, November, 1891.

† Trans. American Society of Mechanical Engineers, Vol. XI, p. 1,064.

for 7 hours on November 7th, and the result was 14.40 pounds of steam per hour per horse-power, which differed from that obtained without jackets, and 17 degrees of superheating, by 1.7 per cent., which is less than the amount of variation ascribable to the accidental errors of the most careful tests. The detailed results are given in Tables I to IV, from which we draw the following general conclusions:

1st. The gain in economy by using the jackets and flue re-heater, with steam superheated about 5° Fahr., [Mr. Kent's conditions] over that obtained when the jackets and flue reheater are not in use, and with steam containing a slight percentage of moisture, is about 3½ per cent.

2d. If the engine is run with and without jackets with slightly moist steam, the probable difference in favor of the jackets, allowing the same gain in economy per degree of superheating with the jackets in use as was observed in the tests without the jackets, will be 3 per cent.

3d. The small advantage of jackets in the Pawtucket engine, as compared with the large gain by jackets reported for other engines, is not ascribable to the small amount of superheating in the steam.

The increase of efficiency for 17 degrees of superheating calculated from the water pressure and revolutions, is 1.5 per cent. against 1.7 per cent. by the indicator cards. This agreement is a satisfactory check on the indicator measurements, but does not verify the figure itself, which depends directly on the measurements of the steam used by the engine.

In the test with moist steam it was necessary to estimate the amount of entrained water. This was done by means of the heat gauge portion of the Barrus Universal Calorimeter. This instrument gave excellent results, and by its use it was possible to accurately regulate the moisture carried over by the steam, so that the average for the entire test is about 0.1 per cent., a quantity much less than the error involved in using any other form of calorimeter. A small globe valve was used to regulate the rate of flow of this water. The readings of the Barrus calorimeter responded quickly to any change of opening in this valve, thus exhibiting its ability to indicate very small amounts of entrained water in a large volume of rapidly moving steam.

Radiation of the calorimeter was allowed for by stopping the engine, and noting the reading of the two thermometers as the steam gradually lost its superheat and became saturated. The pressure of the steam during this experiment was preserved at precisely that maintained during the test.

The pipe leading to the calorimeter projected about 2 inches through the lower side of the steam pipe, at a point where it leads horizontally to the engine. There were no small holes made in the side of the calorimeter pipe, as is recommended by Mr. Barrus, because it was desired to obtain as dry a sample of steam as possible, so that any moisture shown would be the minimum for the whole amount of steam.

The calorimeter drew its steam from a point in the pipe about 1 foot from the thermometer placed in the latter, and about 3 feet from the engine. The amount of steam used by the calorimeter per hour was determined both before and after the test, and is deducted in the tables from the engine consumption.

The indicator springs were standardized directly after the test, and the proper scale was employed in working up the diagrams. As the accuracy of the test does not depend on the absolute readings of the gauges, they were not calibrated.

The average cards are shown in Figs I. to IV.

The water was weighed in a tank and emptied into a second tank, from which it was pumped to the boilers. The capacity of the weighing tank was such that it was filled only once each half hour, at which time the water was brought to a certain level in the second tank. The readings of the height of water in the boilers were taken when the water tank was filled to the mark, so that the rate may be estimated for any portion of the run.

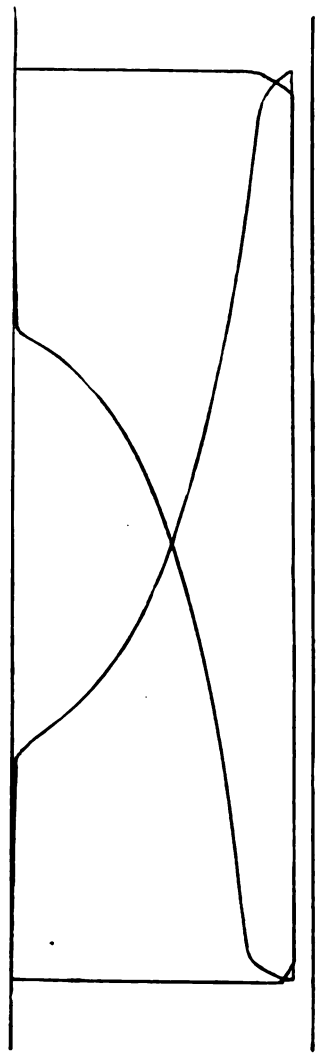


FIG. 1.
Test made November 7th.
Moist Steam.
H. P. Cylinder.
Scale, 80 Pounds per Inch.

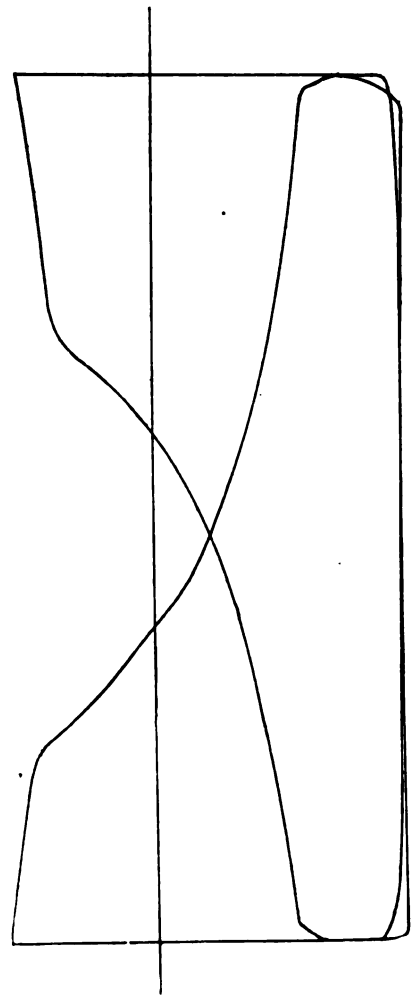


FIG. 2.
Test made November 7th.
Moist Steam.
L. P. Cylinder.
Scale, 10 Pounds per Inch.

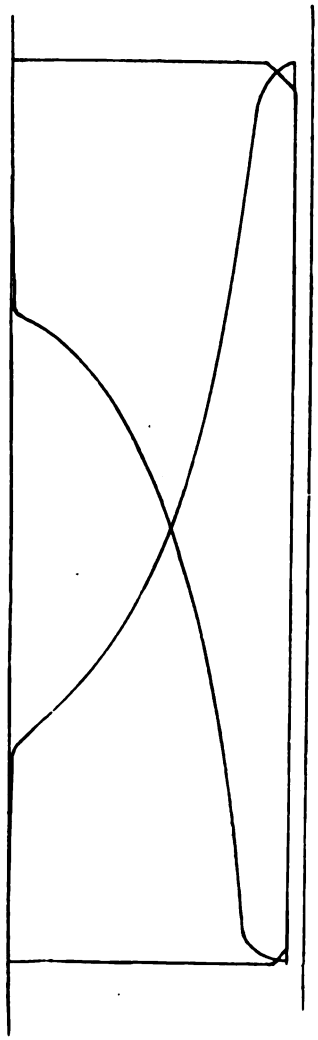


FIG. 3.
Test made November 6th.
Superheated Steam.
H. P. Cylinder.
Scale, 80 Pounds per Inch.

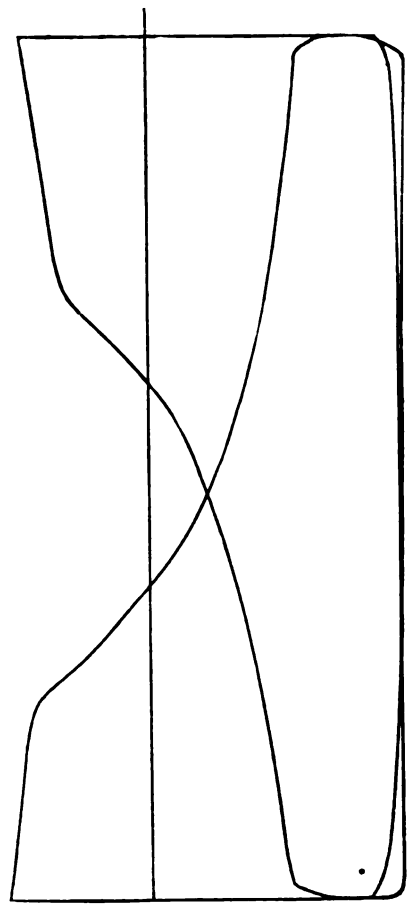


FIG. 4.
Test made November 6th.
Superheated Steam.
L. P. Cylinder.
Scale, 10 Pounds per Inch.

TABLE I.

Steam Consumption of the Pawtucket Pumping Engine, with Superheated and Moist Steam.

Bore of steam cylinders, 15 and 30⅛ inches. Stroke of pistons, 30 inches. Diameter of all rods, 2¾ inches. Jackets and flue re-heater not in use.

CONDITION OF STEAM.	SUPERHEATED 17° FAHR.	0.1 PER CENT. PRIMING.
Date of test	Nov. 6th.	Nov. 7th.
Duration of test in hours	8	7
Average Pressures.		
Boiler, in pounds per square inch above atmosphere	124.0	124.0
Water, in pounds per square inch above atmosphere	110.18	111.40
Vacuum in inches of mercury	27.3	27.2
Suction in feet	13.48	13.95
Barometrical pressure in inches of mercury	30.13	30.07
Average Temperatures in Degrees Fahr.		
Reading of thermometer in steam-pipe 2 feet from steam chest	367.2	350.5
Reading of thermometer for saturated steam at boiler pressure	350.5	350.5
Degrees of superheating	16.7	0.0
Temperature of engine room	72.0	75.8
Mean Effective Pressures in Steam Cylinders in Pounds Per Square Inch.		
High-pressure cylinder, head end	60.24	60.40
High-pressure cylinder, crank end	62.96	63.68
Low-pressure cylinder, head end	11.384	11.419
Low-pressure cylinder, crank end	12.058	12.250
Calculated Quantities.		
Revolutions per minute	48.15	48.18
Total horse-power	138.73	139.95
Steam used per hour	1964.4	2014.6
Steam per hour per horse power	14.16	14.40

TABLE II.

Test in which Steam is Superheated 17° Fahr., made November 6, 1891.

Time.	Height of Water in Gauge Glass, in Inches.				Water Fed to Boilers in Pounds.		Pressure in Pounds per Square Inch.			Vacuum in Inches of Mercury.	Height Suction Water is Lifted, in Feet and Inches.	Reading of Thermometer in Steam Pipe in Degrees Fahr.	Temperature of Engine Room.	Revolution Counter 5 Minutes Later than other Records.
	Boiler No. 1.	Boiler No. 2.	Boiler No. 3.	Sum of Heights.	Total.	Net per Hour Corrected for Water Levels and Steam Used by Barrus Calorimeter.	Boiler.	Receiver.	Water.					
A. M.														
8.30	3.8	4.4	4.0	12.2	.....	.....	124	8.0	112	26.8	13.7	366	71	399,871
9.00	5.1	4.5	3.5	13.1	1,018	.....	124	7.8	109	27.1	13.6	365	72	401,605
9.30	4.6	2.6	5.0	12.2	1,977	1,977	124	7.8	108	27.0	13.6	367	72	402,761
10.00	3.9	4.6	3.4	11.9	2,950	.....	124	7.8	109	26.9	13.5	369	72	404,206
10.30	4.5	2.4	4.3	11.2	3,891	1,959	124	7.8	108	26.9	13.2	367	72	405,653
11.00	4.1	4.3	3.6	12.0	4,928	.....	123½	7.6	109	28.1	13.1	368	72	407,101
11.30	4.3	4.1	4.4	12.8	5,938	1,975	124	7.6	109	27.8	13.0	367	72	408,549
12.00	2.0	1.9	4.5	8.4	6,656	.....	124	7.6	110	27.6	13.0	367	72	409,997
P. M.														
12.30	2.3	2.5	6.6	11.4	7,822	1,947	124	7.8	111	27.3	12.11	369	72	411,431
1.00	5.7	5.2	6.2	17.1	9,119	.....	124	7.8	110	27.1	13.6	370	73	412,876
1.30	5.9	5.2	6.1	17.2	10,086	2,003	124½	7.8	109	26.9	13.6	367	73	414,323
2.00	4.8	4.6	4.9	14.3	10,941	.....	124	7.8	112	27.3	13.8	367	72	416,769
2.30	4.2	4.8	4.5	13.5	11,881	1,958	124	7.8	112	27.1	13.7	365	72	417,212
3.00	4.5	4.1	4.8	13.4	12,854	.....	124	7.6	112	26.9	13.11	367	72	418,655
3.30	5.2	4.2	3.9	13.3	13,854	1,947	123½	7.5	110	28.0	14.4	367	72	420,097
4.00	4.6	4.6	4.1	13.3	14,846	.....	124½	7.6	112	27.8	13.11	367	72	421,541
4.30	4.1	4.2	4.8	13.1	15,832	1,949	124½	7.5	111	27.5	13.8	368½	72	422,985
Average and per hour	4.3	4.0	4.6	13.0	.....	1,964.4	124	7.7	110.18	27.3	13.48	367.2	72	2289.2

TABLE III.

Test in which Steam contains 0.1 *per cent. of Moisture.*

Time, P. M.	Height of Water in Gauge Glass in Inches.				Water fed to Boilers in Pounds.		Pressure in Pounds per Square Inch.			Vacuum in Inches of Mercury	Height that Suction Water is Lifted in Feet and Inches.	Reading of Thermometer in Steam Pipe, in Degrees, Fahr.	Temperature of Engine Room.	Revolution Counter, 5 Minutes Later than other Records.
	Boiler No. 1.	Boiler No. 2.	Boiler No. 3.	Sum of Heights.	Total.	Net per Hour Corrected for Water Levels and Steam Used by Barrus Calorimeter	Boiler.	Receiver.	Water.					
1.15	9.6	14.3	11.0	34.9	.....	.....	124	8.4	114	27.3	14.4	350¼	75	446,778
1.45	12.4	11.5	11.7	35.6	1,116	.....	124	8.6	114	27.1	13.10	350	74	448,221
2.15	13.1	11.7	10.8	35.6	2,187	2,109	124	8.2	114	27.0	13.10	350¼	74	449,664
2.45	11.1	12.8	12.3	36.2	3,270	.....	124	8.0	113	27.3	13.11	350½	74	451,107
3.15	11.6	13.1	10.7	35.4	4,276	2,062	124	8.2	114	27.3	13.11	351	74	452,549
3.45	12.9	11.6	11.7	36.2	5,261	.....	124	8.2	113	27.1	13.11	350½	75	453,990
4.15	10.6	11.5	11.5	33.6	6,318	2,070	124½	8.5	114	27.1	13.11	350½	75	455,430
4.45	12.0	13.4	10.4	35.8	7,426	.....	124	8.2	114	27.5	13.11	351	76	456,870
5.15	12.9	12.8	12.1	37.8	8,573	2,021	124	8.0	112	27.3	13.11	350½	76	458,311
5.45	13.9	13.8	11.9	39.6	9,658	.....	124	7.5	109	27.1	14.0	350½	78	459,762
6.15	11.1	11.5	10.0	32.6	10,317	1,940	124	7.0	108	27.1	13.11	350½	79	461,214
6.45	9.1	10.0	10.2	29.3	11,096	.....	124	7.2	109	27.3	13.11	351	78	462,664
7.15	10.3	11.9	12.1	34.3	12,363	1,941	124	7.2	106	27.1	13.11	350½	78	464,114
7.45	10.5	12.1	10.5	33.1	13,276	.....	124	7.2	108	27.1	14.0	351	76	465,564
8.15	11.5	10.9	11.0	33.4	14,284	1,959	124	7.2	109	28.1	13.11	350	75	467,014
Average and per hour.	11.5	12.2	11.2	34.9	.... ..	2,014.6	124.	7.84	111.4	27.2	13.95	350.53	75.8	2890.9

TABLE IV.

Barrus Universal Calorimeter.

Record of thermometer readings observed during test made November 7th. 1891.

Reading of lower thermometer for dry steam, 290½° Fahr.

Time, P. M.	Temperature in Degrees Fahr.		Time, P. M.	Temperature in Degrees Fahr.	
	Upper Thermometer.	Lower Thermometer.		Upper Thermometer.	Lower Thermometer.
1.20	349	287	3.50	349	288
1.30	349	286	4.00	349	288
1.40	349	288	4.10	348	288
1.50	348	288	4.20	348	288
2.00	348	290	4.30	348	289
2.10	348	290	4.40	348	289
2.20	348	290	4.50	349	289
2 30	348	290	5.00	348	288
2.40	348	290	5.10	348	289
2.50	348	290	5.20	348	289
3.00	348	290	5.30	348	288
3.10	348	289	5.40	348	288
3.20	348	289	5.50	348	288
3.30	348	289	6.00	348	288
3.40	348	289	Aver.	348.2	288.7

Average number of degrees of cooling..... ... 1.8

Corresponding per cent. of priming..... .. .. 0.1

CHROME STEEL—ITS MANUFACTURE AND USES—WITH COMPLETE CHEMICAL ANALYSES.*

BY B. FRANKLIN HART, JR., AND JULIUS CALISCH.

AFTER over a century of steel making, with all the improvements which time and necessity suggested, it was until recently practically impossible to manufacture a strictly uniform grade of very hard metal. To supply this much needed demand scientific men have labored for years, and the outcome has been the so-called "*compound*" steels; alloys of iron with chromium, tungsten, titanium, etc. It is our purpose to discuss but one of these alloys, *i.e.*, *chrome steel*, which we believe has more commercial value than any of the others. Our discussion will be more general than particular, from the fact that parts of the process are kept strictly secret by the makers. Through the kindness of Mr. S. H. Kolen, President of the Brooklyn Chrome Steel Works, we were enabled to witness, and personally examine into, all the details of the manufacture, and we wish to thank him sincerely for the hospitable manner in which we were treated, and for the willingness with which he furnished us with the desired information. We also wish to thank Dr. T. B. Stillman for the many suggestions and valuable aid which he has kindly given.

USES OF CHROME STEEL.

Chrome steel is now used in almost all branches of the arts. The Chrome Steel Co. designates its product as follows:

No. 1 *Extra.* Very high grade, for special purposes.

No. 1. For turning, planing and other tools, used for purposes requiring a steady cut.

No. 1 *A.* Special for punches, heaters, etc.

No. 3. For all kinds of fine-edged tools, chipping chisels and machine shop tools of every description; a grade well adapted for general purposes.

* Abstract of Graduating Thesis.

No. 2. Milder than No. 3, for heavy or drop dies of all descriptions, and best quality sledges, etc.

Mill Picks. Special for mill picks, points, etc.

Rock Drill. Special for mining, quarry and stone cutters, etc.

Tap and Die Steel. For taps and dies of all kinds.

Hammer Steel.

Magnet Steel. A superior brand for permanent magnets.

Cast Spring Steel.

Machinery Steel. Of extra toughness and strength, capable of enduring great friction, and resisting heavy strains; specially adapted to mandrels, shafting for rotary pumps, and other purposes where great strength is required.

Gun or Homogeneous Steel. Extraordinary soft and ductile; well adapted to purposes where tempering and hardening is not requisite.

Jewellers' Roll and Special Forgings.

Round Bars for Prisons or Burglar-Proof Gratings. These bars consist of alternate layers of steel and iron welded together, and are designed for jails, prisons, bank buildings, etc. The gratings or bars are first fitted and then hardened, the steel receiving a temper that will resist any saw, file or drill; while the iron, remaining soft and ductile, will not fracture under heavy blows. This combination of iron and steel is also made into special shapes, and is largely used in safe building.

Chrome steel is also extensively employed in the construction of large bridges, it having been used in the Illinois and St. Louis bridges. Capt. Eads spoke very highly of its property of withstanding an enormous pulling or thrusting stress. In his report, some of the results of which we will give further on, he stated that after many experiments with all grades of carbon steel, he found chrome steel to be the only material he could depend on for certain parts of the structure.

CHROME ORES.

Chromium was discovered in the Var department in France, by M. Vanquelin, in 1897. It is of a grayish-white color (Vanquelin), its lustre is imperfectly metallic. Other chemists give its color as iron-black and brownish-black. Its specific gravity in its purest state is 4.5, but in the article generally found in the market it varies from

3 to 4. Its hardness is 5.5. It may be polished, and then has a fine metallic lustre. It is infusible before the blowpipe, and acts upon the magnetic needle after having been exposed to the reducing flame. It is fusible in borax at a high blowpipe heat, and imparts a green color to the bead. It will scratch glass.

Ores of chromium are pretty generally distributed throughout the earth, but the only ore abundant enough for the purpose of art is the octahedral ore, commonly known as chromate of iron. Chrome ores are found near Baltimore, Md.; Chester, Mass.; California; near Philadelphia, Penn.; Connecticut, New York, North Carolina, in the United States. In Siberia, France, Shetland Islands, Norway, Scotland, Bohemia, Saxony, Greece, and in Brazil, Japan, Canada, Cuba, St. Domingo and the Ural Mountains.

It occurs often in serpentine, forming veins, or in imbedded masses, and is also found crystallized.

The following analyses have been made:

Place.	FeO	MgO	Cr_2O_3	Al_2O_3	SiO_2	Analyst.
1. Chester Co., Pa	35.14	.....	51.66	9.72	2.09 = 99.32	Seybert.
2. Baltimore	36.	.....	39.51	13.00	10.06 = 99.11	"
3. " massive	18.97	9.96	44.91	13.85	0.83 = 98.15	Abich.
4. " cryst	20.13	7.45	60.04	11 85	..... = 99.45	"
					Mn.	
5. Siberia	24.00	.....	53.00	11.00	1.00 1.00 = 100	Langier.
6. Roraas, Nor	25.66	5.36	54.08	9.02	4.83 = 78.95	"
7. Bolton, Ca	35.68	15 03	45.90	3.20	..... = 99.81	Hunt.
9. Lake Memphramagog, U. S.	21.28	18.13	49.75	11.30	..... = 100.46	"
10. Beresof, Sib	8.42	6.68	64.17	10.83	0 91 = 101.01	Moberg.
					Ca.	
11. Baltimore	30.04	.....	63.37	1.95	2.21 2.02 = 99.06	Rivot.
12. Voltena, Tuscany	33.93	.....	42.13	10.84	4.75 = 100.65	Bechi.
					Ni.	
13. Texas, Pa	38.66	.....	63.38	.....	..... 2 25 = 104.32	Garret.

(A System of Mineralogy, Dana, p. 153)

Clark obtained the following average results:

In seventeen (17) analyses, 30 to 40% oxide of Cr, and the average amount of FeO was 15.4%. In twenty-three (23) he found from 40 to 50% Cr_2O_3 and 14.3 FeO. In thirteen (13) he determined from 50 to 60% Cr_2O_3 and 15% FeO. The lowest amount of FeO being 10.6% and the largest 23.14%.

METHOD OF PRODUCTION.

With the possible exception of "Damascus" steel and other "steely irons" made by the ancients, the "crucible" process is the

oldest method of steel making that is used. It was invented in 1770, by Benjamin Huntsman, at Sheffield, Eng., and has been carried on ever since, for the manufacture of fine steel for tools etc.

Chrome steel made by the Brooklyn Company is manufactured by that process. They proceed as follows:

Scrap iron mixed with their own chrome steel scrap, is placed in German clay crucibles lined with plumbago, and a flux of sodium carbonate is sprinkled on top. To this is added the chromium and other ingredients, which are probably tungsten, manganese and carbon. The chromium is in the form of chrome iron ore. The mixture when complete weighs about 100 pounds. The crucibles are placed two abreast in a long, narrow furnace. The fuel used is gas, and is made on the premises. A great heat is produced, greater than when coal is the fuel. (Temperature in the furnace, when coal is used, is about 3,600° F.) The metal is heated until the proper point is reached, which the furnaceman tells by experience, the time generally being about four hours. When the heating is over the draught is turned off, and the furnacemen, swathed in wet cloths about their legs and arms, step directly over the furnace and lift out the crucibles with long tongs, and swing them out on the iron flooring, where the covers are removed. The "pourer" now pours the molten mass into the ingot moulds, a helper in the mean time having skimmed the flux off the top with a "flux stick." The ingot mould tapers slightly from each end; when the ingots get cool enough, they are put into the reheating furnaces, from which they are taken to the rolls and rolled into the required shapes.

The furnaces are of the "Siemen" type, built of common bricks. The gas is let into the furnace, mixed with air, at a point about two feet from the furnace proper. The currents of gas and air are governed by valves manipulated by the furnace-men above. The direction of the current is changed every half hour, from one end of the furnace to the other.

The "combination" metal, spoken of before, is made up as follows:

Strips of steel and iron are laid alternately upon each other, powdered borax being sifted plentifully over each face, and bound together with strips of sheet-iron. The bundles are placed into heating furnaces, and brought to a welding heat, when they are taken out and rolled into any desired shape. The weld is a perfect

one, and to manipulators of carbon steel, is a fact worthy of notice. Chrome steel stands a greater degree of heat without burning than carbon steel, which may account for the readiness with which the iron and chrome steel welds.

Thurston, in his work on Iron and Steel, p. 266, says: "Chrome steel is made by alloying iron and chromium in proportions which are determined by the quality desired."

Feuchtwanger, in the *American Chemist*, Dec. 1871, says: "Chromium steel, made by combining, about 5 per cent. of chromium with cast-iron, possesses most remarkable properties."

Kern, of St. Petersburg, describes his method as follows: "The tables below show the composition of the raw materials, and the recipes for the preparation of chrome steel for various purposes. This steel is especially suitable for steel-casting direct in earth moulds." (*Chemical News*, 1877, 2–36, p. 199.)

A.—Analyses of the raw material for casting steel:

(*a*) Bessemer rolled steel bars:

	I. Per cent.	II. Per cent.
Comb. carbon	0.1000	0.250
Si	0.006	0.010
Mn	0.020	0.030
P	0.010	traces
S	traces	0.005
Cu	none	none

(*b*) Siemens-Martin rolled steel bars:

	III. Per cent.	IV. Per cent.
Comb. C	0.400	0.600
Si	0.020	0.020
Mn	0.030	0.130
S	0.010	none
P	traces	0.001
Cu	traces	none

(*c*) Iron:

	Per cent.
Combined C	0.120
Graphite	traces
Si	0.020
Mn	traces
S	none
P	none

(*d*) Refined cast-iron:

	Per cent.
Combined C	4.250
Graphite	0.100
Si	0.030
Mn	0.010
S	none
P	none

(*e*) Chrome iron-stone:

Chromium oxide (Cr_2O_3)	65.51
Iron oxide (FeO)	31.65
S	none
Foreign matter	2.600
Cu	none

(*f*) Lime (calcined):

CaO	90.750
SiO_2	1.500
FeO	2.750
S	0.010
P	0.005

The chrome iron-stone and limestone are calcined, and then ground.

The raw metallic materials are used in small pieces.

B.—Recipes for the preparation of cast steel:

	I. Kilograms.	II. Kilograms.
Bessemer steel No. I.	24.00	10.00
" " No. II.	5.00	22.00
Iron	5.00	2.00
Chrome iron-stone	0.75	0.65
Limestone	0.25	0.35

The percentage of carbon in steel used was about 0.20 in steel No. I., and from 0.45 to 0.55 in No. II.

	III.	IV.
Martin steel, No. III.	20.50	2.00
" " No. IV	4.50	19.00
Refined cast-iron	8.75	12.00
Chrome iron stone	0.75	1.25
Limestone	0.50	0.75

The percentage of carbon in steel used is from 0.80 to 0.90 in No. III., and from 1.00 to 1.30 in No. IV.

The mixture is placed into previously heated fire-clay crucibles; the chrome iron-stone and the limestone are placed on the bottom of the crucible, and the remainder of the materials added. Ordinary coke-crucible, or Siemens' gas crucible furnaces, are used.

He regards his product as follows:

Steel No. I. For steel plates and rifle barrels.

No. II. For machinery, cannon, tires, axles, etc.

No. III. For instruments, cannon rings, saws, etc.

No. IV. For chisels, planing tools, etc.

PROPERTIES OF CHROME STEEL.

Chrome steel resembles carbon steel in appearance, almost exactly, except that the grain in the former is finer, when the metal is tempered. It is exceedingly hard in the tempered state, being able to resist any tool, and hard enough to scratch glass. Like carbon steel it is very easily oxidized, and is a good conductor of heat and electricity. It possesses every desirable property of carbon steel, while it exceeds it in tensile and compressive strength, resistance to torsional and transverse strains, and in tenacity and toughness, either before or after tempering. It welds readily to iron or to itself, and will not separate at the weld. It will not deteriorate by the continued application of heat, and can be worked in large masses with perfect reliability. It may be forged in the same manner as any good brand of steel, while it should be hardened at the lowest heat at which it will take the temper. The only way in which it can be injured is by dipping it into the hardening mixture when it is too hot. It can be restored, however, by reheating and dipping at a lower heat. It comes from the rolls much more smoothly than carbon steel, being capable of sustaining a greater heat, and thereby taking the form of the rolls more readily. It makes superior magnets, which are extremely permanent.

Chrome steel castings may be forged readily. We saw part of a cog-wheel, which had been cast, and then hammered out into a long strip, which was coiled up. We also saw a chisel forged from a casting and then tempered. Mr. Brady, foreman at the works, has weighed the metal before and after passing through the rolls, and states that from 3½ to 4 per cent. is lost through oxidation. After chrome steel has been hardened, it is almost impossible to cut it with a tool. We attempted to get some borings for chemical analyses and tried to bore with an ordinary ratchet drill. We found

it very hard to make a mark with the best tool in the shop, and boring was out of question. We procured two chrome steel drills, but had no better success, breaking both of them. We had to fall back on the planer, and by cutting across the smallest width, on softened material, obtained our samples for analysis. Its extreme hardness makes it a valuable metal for use in mining operations. The greatest use to which this metal is put, however, is for making the "combination" of iron and chrome steel, used in the manufacture of safes, and in the construction of jails.

Strength.—Numerous experiments have been made for determining the strength of chrome steel. It has always shown its superiority, and a remarkably even set of results. Perhaps the tests made by Captain Eads in the Illinois and St. Louis Bridge, are the most reliable, and convincing of any made.

On the following page is a table of the results of a number of experiments, taken from the "History of the St. Louis Bridge," and they are, without doubt, authentic.

CHEMICAL ANALYSIS.

From the nature of the constituents of chrome steel an analysis of it is a somewhat difficult operation.

We have noted many points of difference in our methods and those adopted by many writers. This is due undoubtedly to the great variation in quality and mixtures used in its manufacture.

Mr. W. Galbraith (*Chemical News*, April 13, 1887) also found difficulty, and declares it to be insoluble in the usual reagents, but says that nitro-hydrochloric acid willl dissolve it in time.

We found that, although it is only slightly soluble in nitric acid, it is entirely soluble in HCl, and also dissolves very readily in nitro-hydrochloric acid.

We dissolved five grains of metal in a mixture of 20 cubic centimeters of HCl and 40$^{c.c.}$ of HNO_3, in about 20 minutes. We also dissolved the same amount of metal, and in rather coarse chips, in HCl of 1.12 sp. gr., in about the same time.

Mr. Galbraith dissolved his metal in 6 parts water to one part sulphuric acid, and found the following proportion of chromium:

	1st determ. Per cent. Cr.	2d determ. Per cent. Cr.
Sample No. 1	0.85	0.83
" No. 2	0.46	0.45

NAME OF MAKERS.	Length in Inches.	Diameter.	Distance Between Collars.	Limit of Elasticity per Square Inch.	Modulus of Elasticity in Pounds per Square Inch.	Breaking Strength. Pounds per Square of Original Section.	REMARKS.
American Tool Steel Co.	11.640	0.550	5.000	71,600	25,600,000	106,500	For Lathe Tools.
Butcher & Co.....	10.875	1.005	6.000	45,300	14,550,000	68,000	Cut from a Chrome Steel Ingot.
" "	8.950	0.560	3.250	42,630	14,868,000	64,900	" " "
" "	9.000	1.003	3.000	35,700	50,000,000	100,100	" " "
" "	11.956	1.005	6.000	43,000	15,450,000	75,950	" " "
" "	11.975	1.010	6.000	40,000	15,600,000	83,827	" " "
" "	10.650	1.010	4.187	49,900	15,598,000	66,160	" " "
" "	10.350	1.010	6.025	44,340	16,900,000	64,290	" " "
" "	10.525	0.567	4.437	47,400	14,615,000	77,400	Bolt from a Chrome Steel Stave.
" "	12.050	0.565	4.100	67,400	20,325,000	99,200	" " "
" "	12.100	0.584	5.000	67,700	13,945,000	104,500	" " "
" "	11.907	0.557	5.875	52,230	13,324,000	110,070	" " "
" "	11.995	0.567	5.900	57,377	15,139,000	100,499	" " "
" "	9.225	0.565	3.000	65,000	11,950,000	107,400	" " "
" "	9.216	0.565	3.000	55,700	24,200,000	107,500	" " "
" "	9.190	0.565	3.000	55,700	16,920,000	105,500	" " "
" "	9.205	0.565	3.000	67,700	15,546,000	103,500	" " "
" "	11.750	0.760	4.000	63,800	22,600,000	147,000	Test Bolt Chrome Steel Ingot.

Mr. R. Schöffel says (*Chemical News*, January 15, 1880) if the percentage of chromium exceeds 30, it will not dissolve on prolonged digestion in hot acid; such alloys are not attached by aqua regia, bromine, or cupric chloride.

Mr. T. Wilm (*Chemical News*, May 14, 1880) warns us against precipitating chromic oxide with ammonia, in glass vessels, because the constituents of the glass are apt to pass into the filtrate.

Mr. Arnold (*Chemical News*, December 10, 1880) analysed three samples of carbon steel, each weighing 198 grains, in .0563 grains of $K_2Cr_2O_7$. (This corresponding to an alloy containing 1 per cent. of Cr.) His results were:

A	0.973 per cent. Cr.
B	1.022 " "
C	0.978 " "

He made three more determinations, in which 1.99 grams of steel were mixed with 0.02815 grams $K_2Cr_2O_7$, corresponding to an alloy containing 0.5 per cent. Cr.

A' gave	0.511 per cent. Cr.
B' "	0.470 " "
C' "	0.508 " "

In another experiment, in which less ammonia was used, an excessive boiling was avoided, and the mixture, same as above, corresponding to 1 per cent. Cr.

No. 1 gave	0.966 per cent Cr.
No. 2 "	0.972 " "
No. 3 "	0.976 " "

In our analysis we followed very nearly the schemes of Magnus Troilius E. M. (Notes on the Chemistry of Iron), which are very compact and reliable.

Carbon.—Five grams of sample are dissolved in a solution of the double chloride of copper and ammonia 300$^{c.c.}$ being used for each determination. Shake the flask containing the sample and solution vigorously for an hour. When all is dissolved, filter through an asbestos filter; wash well with a little HCl and then with plenty of hot water. Empty the contents of the funnel into a flask having a rubber stopper with two holes in it. The arrangement of the apparatus used is shown in the figure. Through the funnel tube in this flask pour 20$^{c.c.}$ of chromic acid solution

(one part by weight of acid to 3 of H_2O). Then pour in 150$^{c.c.}$ of concentrated H_2SO_4. Oxidation of the carbon in the residue sets in at once at a lively rate. After a short time heat is applied until the solution has turned green, the evolution of CO_2 ceased, and white H_2SO_4 fumes have begun to appear. The heat is then removed, and dried purified air is drawn through the apparatus until the flask has cooled down, when the absorption bulbs are weighed. The whole operation requires about an hour. The carbon is obtained as CO_2 directly. This method is a short one and gives very uniform results, and is the only reliable one in the analysis of chrome steel, the color test being valueless, owing to the peculiarity of the metal.

Phosphorus Determinations.—Dissolve five (5) grams of sample in 20$^{c.c.}$ of HCl and 40$^{c.c.}$ of HNO_3, evaporate to dryness, after tendency to spatter has ceased heat one hour longer, in order to completely oxidize and decompose the last traces of iron phosphide, which otherwise would remain insoluble with the silica. Allow the capsules to cool slowly, and add HCl in excess. Boil until all the residue is dissolved, the silica sticking to the sides of the capsule. Add hot water to the concentrated solution, and filter. Care must be taken that all the silica is rubbed off from the sides of the capsule; a glass rod with a piece of rubber tubing on one end is the best thing to use. Wash the silica in the filter paper with dilute HCl and plenty of hot water. Neutralize the filtrate with ammonia—add 50$^{c.c.}$ of molybdic acid solution and shake well. If the yellow precipitate is slow in coming down, a little more ammonia may be added. If too much ammonia is added, a little strong NHO_3 is added to redissolve the iron precipitate. Allow to settle over night at about 40° C., or during a few hours at 80° C.

When the precipitate is all down, filter and wash with about 300$^{c.c.}$ of molybdic acid solution diluted with an equal amount of water—*i.e.*, 300$^{c.c.}$ altogether. The yellow precipitate is then treated on the filter with a little hot ammonia, .96 specific gravity, and the filtrate allowed to run back into the beaker in which the precipitation was made. When all is dissolved, the ammoniacal solution is thrown on to the same filter again, and run into a small beaker. Wash the filter with a little cold water, making the solution up to 20 or 30$^{c.c.}$. To this filtrate add 3$^{c.c.}$ of HCl, 1.12 sp. gr., and a few drops of ammonia to redissolve any yellow salt that may have separated. Add 20$^{c.c.}$ of magnesia mixture and shake until the

white crystaline phosphate of magnesia and ammonia appears. About 6$^{c.c.}$ of ammonia, 96 sp. gr. are then added. If well shaken, the precipitate will now come down in two or three hours; but if time is not available for shaking the beaker may be left standing for about six hours. Filter off the white precipitate, and wash with NH_4HO, 96 sp. gr., diluted with three times its volume of H_2O. About 80$^{c.c.}$ of this mixture will have washed it sufficiently. The sides of the beaker must be well rubbed with the tubing on the glass rod, to get all of the white precipitate. The filter with the white precipitate is put, while still wet, into a platinum crucible and ignited. The ignited precipitate is pyrophosphate of magnesia, $Mg_2P_2O_7$, containing 27.95 per cent. of phosphorus.

Tungsten Determination.—Dissolve five grams of sample in a capsule, in 20$^{c.c.}$ of HCl and 40$^{c.c.}$ of HNO_3—evaporate to dryness as in the phosphorus determination, except that the heating need not be so strong and protracted.

The presence of tungsten is at once indicated by the yellow color of the tungstic acid WO_3, which all separates with the silica. Filter and wash with H_2O, to which a little HCl has been added to prevent the WO_3 from passing through the filter. The tungstic acid is then dissolved on the filter in hot NH_4HO, and is thus separated from the silica. The filtrate is concentrated so as to allow of its being poured into a weighed platinum crucible, in which it is evaporated to dryness, ignited, and weighed as WO_3, containing 79.3 per cent. of tungsten.

Chromium Determination.—Dissolve two grams of samples in HCl, 1.12 sp. gr., in the flask. The neck of the flask should be closed with a rubber stopper with two holes in it, in which are inserted pieces of glass tubing having short pieces of rubber tubing on the ends outside.

To prevent oxidation, we tried the following plan which was very successful. Carbonic acid gas was generated, and passed into the flask containing the steel through one of the tubes, and let out into the air through the other tube. The solution of HCl and the steel is boiled until everything is dissolved, then put in a little Zn, and allow that to dissolve also; we now have a pure green solution. Nearly fill the flask with cold water after having closed the ends of the rubber tubing with glass rods, and if much free acid be present add a little carbonate of soda. Neutralize the solution with powdered carbonate of barium in excess.

Cork the flask tightly and allow it to stand for twenty-four hours at ordinary temperature, with occasional shaking, Cr_2O_3 and a little Fe_2O_3 are hereby precipitated, whilst all the $FeCl_2$, $Mn\ Cl_2$, etc., remain in the solution. Filter off the precipitate together with the excess of barium-carbonate, wash with hot H_2O, put it back into the same flask and redissolve in HCl by boiling. Filter, to get rid of filter paper from above, and to the clear solution add N H_4HO, and boil off excess.

The Cr_2O_3 and the Fe_2O_3 are hereby precipitated, while all the barium remains in solution. Filter off the precipitate, wash well with hot water, dry, ignite and fuse in a platinum crucible with sodium-carbonate and a little nitrate of soda. Extract the fused mass with hot water, boil and filter off the residual iron oxide.

The filtrate contains all the chromium as the yellow sodium chromate. Evaporate this to dryness, moisten with a little HCl and dissolve it in H_2O. Filter off the insoluble residue which is silica. Acidify the filtrate with HCl, add sodium sulphite until the yellow color disappears, and heat to boiling. The CrO_3 is hereby instantly reduced to Cr_2O_3. To the boiling solution, add NH_4HO, in slight excess. After boiling for a few minutes the chromic oxide is precipitated, continue boiling until the smell of NH_4HO has almost completely disappeared.

Filter off the chromic oxide, ignite in a Pt. crucible and weigh as Cr_2O_3 containing 68.62 % of Cr.

Manganese Determination.—In this determination we made use of two methods, which were as follows:

Troilius.— Dissolve 5 grams of sample in about 150^{c} of HNO_3, 1.20 sp. gr. Boil until the bulk is about 100$_{c\,c}$. Add crystals of chlorate of potash, and all the Mn separates as dioxide MnO_2 insoluble in strong HNO_3. Boil the precipitated Mn for a few minutes; add cold strong HNO_3, and filter off on an ordinary asbestos filter; wash twice with cold strong HNO_3, and four times with cold water. Place the precipitate into a beaker. Boil the precipitated dioxide with HCl until all the chloride is driven off. Dilute with H_2O, and filter off the asbestos. Add a little acetic acid to the hot filtrate, and neutralize with NH_4HO. Boil, and allow the precipitated basic acetate of *Fe* to settle. Filter, and wash well with hot water. To the filtrate add an excess of strong NH_4HO, and then with vigorous stirring, a few c.c.'s of bromine, by which the hydrates of the higher oxides of Mn are precipitated.

Allow this to cool, standing over night, when the Mn settles; filter, ignite in a Pt crucible and weigh as Mn_3O_4 containing 72.08 per cent. of Mn.

Determinations, numbered No. 2 in the various grades, were made according to this method.

Fresenius.—Dissolve 10 grams of sample in dilute H Cl, with the addition of HNO_3. Evaporate to dryness to separate the Si O_2. Redissolve in HCl, filter. Make the filtrate up to 1500$^{c.c.}$, with H_2O—warm—add dry Na_2CO_3 until the solution becomes dark sherry red, and looks almost like a precipitate, but there must not be a distinct precipitate, then add about 20 grams of dry Na $\bar{A}$ and boil the precipitate about 15 minutes. Allow it to settle, and pour off 750$^{c.c.}$ of the supernatant liquid, this being one-half of the whole original solution, and therefore corresponds to 5 grams of sample. Concentrate the solution to about 300$^{c.c.}$ Add Na_2CO_3 to alkaline reaction—boil—and add a little sodium hydroxide. Collect the precipitate on a filter. Dissolve in HCl. Boil the filtrate to expel chlorine. Add Na_2CO_3 until a slight deepening of color, due to the presence of ferric chloride, indicates that the solution is neutral. Add $Na\bar{A}$, boil, and filter. Precipitate the Mn in the filtrate by Br, filter dry, ignite, precipitate, and weigh as Mn_3O_4.

Determination numbered No. 1 in the samples were treated by this method.

Comparing the two methods we think that Troilius is the better. It does not require so much manipulation, and not quite so much experience. The Troilius scheme is simple, concise, and has given an even set of results.

Sulphur Determination.—Ten grams of sample are put into a half litre flask with a long neck. This flask is connected with absorption bulbs containing HCl, 1.12 sp. gr., and about 5$^{c.c.'s}$ of bromine. A large tube is placed between the flask and the bulbs, causing the vapor to condense and flow back into the flask while boiling. The flask is also provided with a thistle tube. The connections being made, 200$^{c.c.}$ of boiling H_2O are run in through the thistle tube. The air is thus driven out of the flask; 200$^{c.c.}$ of strong HCl are then added. When the gas has begun to work slowly, heat is applied, and the solution boiled until all the steel is dissolved. Remove the heat, asperate with an aspirator and run it about 15 minutes. Rinse the contents of the bulbs into a beaker, add 10$^{c.c.}$ of $BaCl_2$ solution, heat until the Br is all driven off and

the $BaSO_4$ has settled. Filter off on a double ashless filter, wash with hot H_2O, ignited and weighed as $BaSO_4$ containing 13.72 per cent. of S.

Silicon Determination.—Five grams of sample are dissolved in such a quantity of dilute H_2SO_4, that for each gram of metal there will be $2^{c.c.}$ of the strong acid.

We added $20^{c.c.}$ of H_2O to $10^{c.c.}$ of H_2SO_4. When all is dissolved, add strong HNO_3 until no more effervescence occurs. Evaporate to dryness, moisten with a little HCl and dissolve in a small excess of boiling H_2O. Filter off the silica, wash with dilute HCl and hot H_2O, ignite, and weigh as SiO_2 containing 46.7 per cent. of silicon. This process is used when tungsten is absent.

Iron.—The iron we will determine by difference, having found all the other constituents of the metal. We might have made separate determinations, but as a rule it is always determined by difference. Following this is a summary of the results of our analysis:

No. 1 Steel.

Summary.

No. 1.	Per Cent.
Carbon	1.1077
Phosphorus	0.0354
Chromium	0.7563
Silicon	0.1292
Sulphur	0.0065
Manganese	0.0219
Iron	97.9430
Total	100.0000

No. 1 Steel.

Summary.

No. 2.	Per Cent.
Carbon	1.1453
Phosphorus	0.0410
Chromium	0.6827
Silicon	0.1339
Sulphur	0.0058
Manganese	0.0221
Iron	97.9692
Total	100.0000

No. 3 Steel.

Summary.

No. 1.	Per Cent.
Carbon	0.7253
Phosphorus	0.0186
Chromium	0.5127
Silicon	0.1754
Sulphur	0.0052
Manganese	0.0103
Iron	98.5525
Total	100.0000

No. 3 Steel.

Summary.

No. 2.	Per Cent.
Carbon	0.7417
Phosphorus	0.0158
Chromium	0.5283
Silicon	0.1614
Sulphur	0.0058
Manganese	0.0103
Iron	98.5367
Total	100.0000

Magnet Steel.

Summary.

No. 1.	Per Cent.
Carbon	0.9571
Phosphorus	0.0522
Chromium	0.4940
Tungsten	0.6186
Silicon	0.0550
Sulphur	0.0043
Manganese	0.0167
Iron	97.8021
Total	100.0000

MAGNET STEEL.

Summary.

No. 2.	Per Cent.
Carbon	0.9653
Phosphorus	0.0438
Chromium	0.5974
Tungsten	0.7614
Silicon	0.0613
Sulphur	0.0050
Manganese	0.0167
Iron	97.5491
Total	100 0000

ROCK DRILL STEEL.

Summary.

No. 2.	Per Cent.
Carbon	0.8508
Phosphorus	0.0218
Chromium	0.5455
Silicon	0.1246
Sulphur	0.0057
Manganese	0.0112
Iron	98.4404
Total	100.0000

ROCK DRILL STEEL.

Summary.

No. 2.	Per Cent.
Carbon	0.8480
Phosphorus	0.0190
Chromium	0.4082
Silicon	0.1329
Sulphur	0.0050
Manganese	0.0094
Iron	98.5775
Total	100.0000

MAGNITUDE OF MOLECULES AND LIGHT WAVES.

BY PRESIDENT MORTON.

IN a previous number of the INDICATOR, Vol. VIII., p. 57, some curious data as to the number of molecules in a small volume of air or like gas were given, and it was the intention of the writer at that time to couple with them certain facts as to the relative size of material molecules and light waves and the relations of both to sensible magnitudes.

At the time of writing, however, some memoranda had been mislaid, and the subject was set aside, until, as has now happened, the missing document should be recovered.

When we hear that the successive vibrations in a light ray of average wave length number about 600 million of millions in a second the natural impression is that they must be submicroscopic in dimensions.

This, however, is far from being the case. The actual length of the waves in such a ray is about one fifty-thousandth of an inch. The parallel rulings on the glass plates, known as Nobert's test plates, which are employed to test the defining powers of lenses, have been not only "resolved" but photographed when only one one hundred and fifty thousandth of an inch apart (*i. e.*, 150,000 to the inch). In other words, four such lines, spaced as in these rulings, could be drawn within the length of an average wave of light. This shows that the size of the ultimate particles or molecules of the glass must be very much smaller than the waves of light, since several furrows may be ploughed through them within the width of an average wave.

All these magnitudes are, however, far beyond our direct perception or powers of realizing, but we may at least get at some

sense of our shortcomings in power of conception from the following.

A maker of these "test-plates," named Webb, many years ago, made for the Army Medical Museum at Washington a specimen of microscopic writing on glass. This writing consists of the words of the Lord's Prayer, and occupies a rectangular space measuring $\frac{1}{254}$ by $\frac{1}{441}$ of an inch, or an area of $\frac{1}{112014}$ of a square inch.

The lines of this writing are about as broad as those on the test plates, which are $\frac{1}{50000}$ of an inch apart. They are, therefore, about as wide as average light waves. Now then to get some idea of the magnitude or minuteness of this writing.

There are in the Lord's Prayer 227 letters, and if, as here, this number occupies the $\frac{1}{112014}$ of an inch, there would be room in an entire square inch for 29,431,458 such letters, similarly spaced.

Now the entire Bible, Old and New Testaments, contains but 3,566,480 letters, and there would, therefore, be room enough to write *the entire Bible eight times over on one square inch of glass*, in the same manner as the words of the Lord's Prayer have been written on this specimen.

Such a statement, without doubt, staggers the imagination, but the figures are easily verified and are certainly correct, and the whole statement at least serves to bring home to us the limited nature of our mental capacities as compared with the facts of the universe.

It also furnishes an interesting suggestion in a very different subject.

It has been often stated that a physical basis of memory may exist in permanent structural modification of the brain matter constituting the surface of the furrows. In a highly developed brain this surface amounts to 340 square inches, and it would, therefore, appear that the entire memories of a lifetime might be written out in the English language on such a surface, in characters capable of mechanical execution, such as those of the Webb plate at Washington. See *The Lens*, December, 1873, p. 225 (Chicago). Also, Trans. of Micro. Soc. (London), 1862, III., Vol. X., p. 69.

REFERENCES AND ABSTRACTS.

ANALYTICAL CHEMISTRY AND TECHNOLOGY.

On Standard Sperm Candles. W. C. YOUNG, F. C. S., Gas Examiner to the Corporations of London, etc. (*Journal Society of Chemical Industry*, 1891, p. 184.) "In conclusion I may mention some experiments I have made with one of the latest proposed standards of light, viz.:—Harcourt's 16-candle standard. In the early part of this paper I stated that I had found that 2½-inch flames in the 16 candle test burner of coal-gas, carburetted coal-gas (*i. e.*, coal-gas passed over cold petroleum spirit as in Lowe's carburetter, or hot as in Maxim's), and of Pintsch's oil-gas, all possessed the same lighting power, but that a similar length of flame of Steinbergh's carburetted water gas, of a mixture of coal-gas and carburetted water-gas made by Meeze's process, and of coal gas enriched with petroleum oil instead of cannel coal, as in Good's patent (in which the petroleum is injected into the gas retorts when the charge is nearly exhausted), gave much higher results.

My experiments show that with Steinbergh's gas the 2½-inch flame equals 18 candles, with coal gas and Meeze's carburetted water gas, 16.4 to 17.4, according to the proportion of the latter present, and with gas obtained by Good's method, 15 candles.

Lowe's jet photometer also gives equally erroneous indications with carburetted water gas. With a mixture of coal gas and Meeze's carburetted water-gas I have on several occasions found the jet photometer indicate 16-candles when the quality has really been over 18. I have no doubt that all other standards of light in which the gas under examination is employed, such as Methuen's and Sugg's 10-candle standard, would be found to be effected in the same way.

The Analysis of Ferro-Chromium, Ferro-Aluminium, Ferro-Tungsten, Ferro-Silicium and Ferro-Titanium. A. ZEIGLER. (*Ding. Polyt. Journal*, Vol. 279, pp. 163–166.)

The Estimation of Aluminium in Iron and Steel. A. CARNOT. (*Monit. Scient.* 37, 14–15.)

The Determination of the Heating Value of Coal. H. BUNTE. (*Journal Society Chem. Industry*, Vol. X., p. 350.)

On the Determination of the Strength of Various High Explosives. W. WALKE. (*Journal Amer. Chem. Society*, XII., 256). As the result of many experiments the following table has been arranged to show the order of strength of the various explosives (nitro-glycerine being taken as the standard and rated at 100.)

1.	Explosive gelatine, made from nitro-glycerine after the Vouges process	106.17
2.	Hellhoffite	106.17
3.	Nitro-glycerine (made Nov. 19, 1889)	100.00
4.	Nobel's smokeless powder	92.38
5.	Nitro-glycerine, (made Jan. 29, 1890, and tested on the same day)	92.38
6.	Explosive gelatine, (made from nitro-glycerine No. 5)	88.95
7.	Gun-cotton, (U. S. N. Torpedo Station, 1889)	83.12
8.	Gun-cotton, (Stowmarket, 1885)	83.12
9.	Nitro-glycerine, (made according to the French process and tested the same day)	81.85
10.	Gun-cotton, (Made in Artillery School Laboratory)	81.31
11.	Dynamite, No. 1	81.31
12.	Dynamite, de Trouzl	79.31
13.	Emmensite	77.86
14.	Amide powder	69,87
15.	Oxonite, (picric acid, fused before being added)	69.51
16.	Tonite	68.24
17.	Bellite	65.70
18.	Oxonite, (picric acid not fused)	64.24
19.	Rack-a-rock	61.71
20.	Atlas powder	60.43
21.	Ammonia dynamite	60.25
22.	Volney's powder, No. 1	58.44
23.	Volney's powder, No. 2	53.18
24.	Melinite	50.82
25.	Silver fulminate	50.27
26.	Mercury fulminate	49.91
27.	Mortar powder, Dupont	28.13

Estimation of Phosphorus in Pig Iron by the Centrifugal Process. C. REINHARDT, (*Chem. Zeit.* 1891, XV., p. 410). This process, which is being rapidly introduced into the laboratories of German iron and steel works, is as follows:

Two grammes of pig iron (1 to 0.5 gramme if there be over 1 per cent. of phosphorus) are treated in a 500c.c. flask with 60c.c $H N O_3$ (sp. grav., 1.2), heated until solution is complete and all the nitrous acid is expelled. A solution of $K_2Mn_2O_7$ (28 grammes of the crystals to 1,000c.c. water) is added in the following amounts: 10c.c. for gray iron, 20c.c. for white iron, 30c.c. for spiegel and ferro-manganese, boiled, then solution of potassium oxalate * added slowly until the liquid is colorless.

* The potassic oxalate solution contains 250 grammes of the crystals to 1 litre of H_2O.

After boiling, it is cooled, diluted to 250c.c., 25c.c. of the solution are transferred to a 200c.c. flask, 10c.c. acid ammonium nitrate solution added, heated to 70° C, 10c.c. ammonic molybdate* added and the mixture agitated for 2 minutes and cooled. The precipitate is then poured into a pear-shaped glass vessel with graduated stem, the last portions of the precipitate being washed in with water containing a little ammonium nitrate; the vessel is then stoppered and placed in the centrifugal machine. The latter is rotated for 2 minutes at the rate of 20 revolutions per second, and then violently brought to a full stop, the vessel removed, closed, tapped on the table until the precipitate has a level surface, and the volume read off.

A series of analyses given by the author show a difference from 0.005 to 0.026 per cent. of phosphorus in different classes of iron.

Incandescent Gas Lighting. W. MacKean, F. C. S. (*Journal Soc. Chem. Industry*, 1891, p. 196.) A paper giving the composition of the various mixtures of the rare oxides to produce white. yellow or orange lights—also, a series of experiments upon life of the various mantels, with varying consumption of illuminating gas.

The Corrosion of Iron. Robert Irvine, F. R. S. E. (*Journal Soc. Chem. Industry*, 1891, p 237.) It is abundantly manifest that the use of two dissimilar forms or kinds of irons becomes a source of danger and loss.

If plates of cast and malleable iron are placed in water, and wires from each connected with a galvanometer, deflection of the needle at once takes place, whilst if both plates be either of cast or malleable iron no galvanic action ensues.

It naturally follows that any structure if it is to be free from the danger I have referred to, should be composed of the same variety of iron; and, by observing this matter, the constructors of the Forth Bridge, where mild steel was used throughout in its construction, have doubtless avoided the mistake made in the construction of the old Tay Bridge, which was a combination of cast and malleable iron, neither being of very good quality. After its destruction, the commission appointed by the Government to inquire into the cause of its collapse, found that the rivets of the malleable iron portion had become loosened, and the evidence all pointed in the direction that this bridge was so constructed that it formed a huge galvanic circle, in which the malleable iron was weakened beyond the point of stability.

The universal use of paint in the preservation of such structures is well known, but I believe the use of all metallic pigments has a tendency, wherever the iron is not thoroughly covered, to provoke the danger they are intended to remedy. A varnish, such as boiled linseed oil alone, which on exposure to air dries up into a tenacious elastic coating, seems

* Ammonic molybdate solution made by dissolving 180 grammes molybdic acid in 450c.c. of water and 450c.c. of 20 per cent. ammonia, filtered, and 450c.c. of the filtrate added to 1 litre of HNO_3 sp. grav. 1.2.

to me to be the proper material to be used for the protection of iron structures.

The Utilization of Coke-Breeze. G. FRERE, (*Compt. Rend. de la Soc. Tech. de l'Ind. du Gaz en France*, 1890, p. 358). An average analysis indicates the composition to be:

Moisture	5 per cent.
Carbon	84 "
Ashes and clinkers	11 "

and while numerous experiments have shown that coke-breeze cannot be used alone as a fuel for heating boilers, the results obtained, however, gave the proportions required of a mixture of coke-breeze and small coal, to produce the best results at a minimum expense.

Two 30-H. P. Babcock & Wilcox steam boilers were used with coke-breeze and small coal, using a forced draught, obtained by means of a Bourdon steam-blower.

The results obtained with the various proportions of small coal and coke-breeze are shown in the following tables:

NO. 1.—*With Breeze and Small Coal.*

Length of trial		10 hours.
Average steam pressure		6 atmospheres.
Water evaporated		14,109 lbs.
Small coal used	1,898 lbs.	
Breeze used	467 lbs.	
		2,365 lbs.
Normal horse power		30
Actual power developed		42.66 h. p.

NO. 2.—*With Breeze and Small Coal.*

Length of trial		6 hours.
Average steam pressure		6 atmospheres.
Water evaporated		7,584 lbs.
Small coal used	856 lbs.	
Breeze used	587 lbs.	
		1,443 lbs.
Normal horse power		30
Actual power developed		36.39 h. p.

NO. 3.—*With Breeze and Small Coal.*

Length of trial		6 hours.
Average steam pressure		6 atmospheres.
Water evaporated		5,021 lbs.
Small coal used	370 lbs.	
Breeze used	794 lbs.	
		1,164 lbs.
Normal horse power		30
Actual power developed		28.33 h. p.

NO. 4.—*With Breeze and Small Coal.*

Length of trial		6 hours.
Average steam pressure		6 atmospheres.
Water evaporated		5,556 lbs.
Small coal used	326 lbs.	
Breeze used	849 lbs.	
		1,175 lbs.
Normal horse power		30
Actual power developed		28 h. p.

The proportions of breeze and small coal given in the last example represent the limit for practical working.

The Welsbach Incandescent Light. Prof. EDWARD HART. (*Journal Analytical and Applied Chemistry*, 1891, p 41.) This is a description of a visit of the members of the American Chemical Society to the factories of the Welsbach Incandescent Gas Light Co., at Gloucester, N. J., and gives in detail, with drawings, the methods of preparation of the mantles. In concluding the article, Prof. Hart states as follows: "The demand for this light is large and increasing. At the time of our visit the works were turning out 8,000 per week.

"In addition to the manufacture of their lamps, the company had on exhibition a magnificent collection of rare minerals and the salts derived from them.

"It consisted of 150 kilos lanthanum and ammonium nitrate.
100 " neodymium " "
10 " praseodymium " "
10 " yttrium oxalate from fergusonite.
10 " " " " gadolinite.
50 " zirconium nitrate.

Specimens of salts of erbium, yttrium, thorium and cerium; oxides, carbonates, sulphates, nitrates, chlorides, acetates, oxalates of neodymium and praseodymium, cerite, monazite, somarskite, allanite, zircons."

Standard Method of Sampling Iron Ores. All samples shall be taken from the vessel while unloading, and none shall be taken before "bottom is made." As soon as bottom is struck under each hatch, exposing faces of ore from top to bottom of the cargo, the sampler is to begin sampling as follows:

Starting at one side of a face of ore, he is to sample the whole of it at intervals of eighteen inches, the exact point being determined by a measuring rod. When the end of the rod falls upon lump ore, lump ore is to be taken into the sample at that point. When the end of the rod falls upon fine ore, then fine ore is to be taken into the sample; the same weight as nearly as possible shall be taken at each sampling point. All the faces [illegible] be sampled in this manner; this sampling shall be repeated at inter-

vals of two hours which would require not less than four samplings to be made of an ordinary cargo, and no less than three samplings shall be made of any cargo of over 500 tons.

The total weight of the sample shall in no case be less than 300 pounds, and the whole of it shall be ground fine enough to pass through a No. 3 sieve. After being put through this sieve, the samples shall be spread out, thoroughly mixed, and quartered repeatedly, rejecting alternate quarters each time, until the sample is small enough for shipment to the laboratory, namely, four or five pounds. Before receiving the sample at the laboratory it shall all be ground fine enough to pass through a No. 6 sieve, after which it shall be quartered again, and the remaining portion so reduced as to pass through a No. 80 sieve, again quartered, and put through a No. 120 sieve; this last powder shall be recognized as the sample of the cargo from which the ore is taken, and the analysis of this powder, *dried at* 212° *Fahr.*, shall be accepted as the analysis of the cargo.

The analyst shall, in case it is so desired, send to either the buyer or seller a portion of the powdered sample from which the analysis has been made, and also a copy of said analysis. Whenever the above method of sampling shall be made a part of any contract, it shall be understood that the buyer and seller shall divide equally the expenses of such sampling and analysis, *unless* it is otherwise specified.

Both buyer and seller shall have a right to have a representative present while samplings are being made, and if sampling is not carried out properly, to object at the time; but if no objection shall be made, the sampling shall be considered satisfactory. (From a pamphlet issued by Rattle & Nye, Cleveland, O.)

The Valuation of Aluminium and its Alloys. F. REGELSBERGER. (*Zeitschrift angew. Chemie.*, 1891, p. 360.). The pure metal is white, but as generally obtained is bluish-white, the blue color being due to impurities. The fracture of the pure metal is finely crystalline and silky, the presence of iron or silicon rendering the structure coarser. When cast the pure metal contracts and the surface shows markings of fine needles—iron and silicon, even in small amounts, causing the markings to disappear.

Determination of Silicon.—2-4 grammes of the metal in fine cuttings are placed in a platinum dish with six times as much *pure* caustic potash and 50c.c. warm water. When solution is complete, neutralize with HCl, evaporate to dryness, take up with HCl and H_2O and filter. The author considers the silicon to be present in two forms—the unoxidizable form existing as free silicon, the oxidizable combined with the aluminum as aluminum silicide. Their amounts are determined as follows:

The portion insoluble in HCl when ignited gives

$$p = x\,(\mathrm{Si}) + z\,(\mathrm{Fe_2O_3}) + y\,(\mathrm{SiO_2});$$

after fusing with K Na CO_3 and evaporating to dryness with HCl, there is obtained a new weight q = the total silicon as SiO_2.

Now, $\Delta = q - (p - z)$, or the oxygen necessary to convert the silicon into silica; then $32 : 28 = \Delta : x$, gives the amount of the unoxidizable or

graphitoidal silicon, and from the total may be obtained, by difference, the amount of chemically combined silicon.

Determination of Aluminium.—Two grammes, in borings, are dissolved in KHO solution and diluted to 200c.c.

50c.c. of this solution are boiled with 20 grammes of ammonium nitrate, the precipitate formed, well washed, ignited and weighed. The weighed precipitate is finely ground, a weighed portion boiled with water to remove alkali; another portion is fused with bi-sulphate of potassium, dissolved in water and the silica filtered, ignited and weighed. The amount of the whole precipitate may be calculated from these results.

The Practical Application of Magnesia Cement. CARL OTTO WEBER, Ph. D. (*Jour. Soc. Chem. Industry*, X., p. iii.) The formula introduced by the author, for a new and superior cement is

100 Magnesia,
15 Silicic acid,
90 Magnesium chloride, 80 per cent.

It has a tensile strength equal to 1,788 lbs. per inch square; the introduction of emery No. 24, in the following proportions, produced a cement whose tensile strength was 2,236 lbs. per inch square.

Magnesia.....	20 parts
$MgCl_2$.6 Ag. 80 per cent. sol.....	20 "
Emery No. 24	100 "

Considering the great strength of compounds of magnesia cement, it will appear that it is very well adapted for the manufacture of emery wheels. If for Sorel's magnesia cement the silica magnesia cement be substituted, the wheels produced are of remarkable toughness, and, perhaps, as safe as the emery wheels, considered the safest of all—namely, those made with india-rubber as cohesive matter. The proportion of cement in the magnesia emery wheels ought not to be less than 20 per cent. of the emery; it never exceeds 50 per cent. Of a similar nature is the use of this cement for the manufacture of millstones. The face of these stones can be made from emery, with a backing of crushed flint. Such millstones are, in hardness, lasting quality, and general efficiency, very much superior to natural stones, especially for the grinding of very hard material. The greatest use of the magnesia cement, however, seems to lie in its application for the manufacture of artificial building stone, as very small amounts of the cement are required to form remarkably strong stones.

The most important question is, of course, whether they will resist the influence of the atmosphere as well as a good natural building stone.

As far as artificial stones from Sorel cement are concerned, this question must be answered in the negative ; but stones made from the silica magnesia cement withstood the influence of the atmosphere for over 12 months without showing the slightest sign of deterioration.

The Production and Utilization of Artificial Cold. G. RICHARD. (*Bull. Soc. d'Encouragement l'Industrie National*, 1889, p. 629–773.) This elaborate memoir was compiled by the author at the request of the organizing committee of the *Congress Internationale de Mechanique Appliqué*. The whole subject of the machinery employed for the production of artificial cold is exhaustively treated. No less than 246 patents are referred to. The memoir is divided into the following sections: Theory of Air Machines, Liquefaction, Machines working with Liquefiable Gases other than Ammonia, Absorption Machines, Applications of Refrigeration, Manufacture of Ice, Cooling of Buildings, Preservation of Meat. (*W. H. G., Jour. Soc. Chem. Industry*, 1891, p. 121.)

Determination of Manganese in Manganiferous Slags and Ores. G. L. NORRIS. The manganese in slags from blast furnaces making spiegel, and in open-hearth slags, is easily and rapidly determined in the following way:

1 gramme of the finely powdered slag is placed in a 4-oz. Griffin beaker, moistened slightly with water to prevent caking and 50c.c. of nitric acid of 1.42 sp. grav. added. Bring to a boil and while the slag is in suspension, add 3 or 4c.c. of hydrofluoric acid. The slag is rapidly decomposed and the silica driven off. Boil the solution for 2 minutes to drive off any remaining hydrofluoric acid, then transfer to a larger beaker, or a precipitating flask, add more nitric acid, bring the solution to a boil and precipitate the manganese with $KClO_3$. Filter off the manganese di-oxide upon an asbestos filter. The manganese di-oxide may either be dissolved in standardized oxalic acid or ferrous sulphate solution and the excess of the solvent titrated with permanganate of potassium and the amount of manganese calculated; or the manganese may be finally weighed as the pyrophosphate. (*Jour. Analytical and Applied Chemistry*, 1891, p 429.)

The Purification of Water by Metallic Iron. HENRY LEFFMANN.

The process may be described as follows:

Metallic iron, in the form of either cast iron borings or steel punchings, is placed in a cylinder so arranged that by a slow rotation the iron may be continuously showered through the water, which is being passed at a moderate speed through the same cylinder. The chemical action consists in great part in the conversion of the iron into ferrous carbonate, through the agency of the carbonic acid, which partly dissolves in the water and partly remains suspended in the form of dark green turpidity. On exposure to air the iron is converted into ferric hydroxide, which, settling rapidly, carries down with it and oxidizes the organic matter. The flocculent sediment permits of rapid and perfect filtration through a simple sand filter. For evidence of its success and efficiency it is only necessary to point to the continued successful use of the process at Antwerp, Dordrecht, Paris, Nancy and other places.

The advantages of the Anderson process, as this method is called over other methods of purification and filtration, are among others:

1st. The avoidance of the use of chemicals.

2d. The automatic and continuous renewal of the active surface of the iron.

3d. The removal of nitro-organisms to such an extent that the water as delivered is practically sterile.

This extraordinary fact is conclusively proved by the experiments made at Antwerp by Professor Van Ermengem, on samples drawn at frequent intervals from the delivery pipes of the sand filters when supplying over two million gallons per day. The one hundred thousand microbe colonies contained in a cubic centimeter of the Nethe water are reduced to an average of five colonies, which, considering the great difficulty of avoiding all contact with the air in these delicate tests, is equivalent to a complete destruction of the micro-organisms. (*Jour. Anal. and Applied Chem*, 1891, p. 450.)

A Universal Gasometer. (Gasometer, blast, force-pump and filter apparatus combined.) By DR. EICHHORN. (*Zeit. fur. Anal. Chemie.*, 1891, p. 446.)

The Official Testing of Thermometers. By H. F. WIEBE, Member of the Royal Physical Institution, Charlottenburg, Germany. (*Zeit. fur. Anal. Chem.*, 1891, p. 8.)

The Use of the Calorimetric Bomb for Determining the Heat of Combustion of Coal. By M. SCHEURER-KESTNER. (*Compt. Rend.*, Vol. 112, p. 233.)

The Analysis of Illuminating Gases. BY V. P. LEWES. (*Jour. Soc. Chem. Industry*, 1891, p. 411).

Electro-Metallurgy of Aluminium. A. MINET (*Compt. Rend.*, 112, 231, *Jour. Soc. Chem. Industry*, 1891, p. 470.—Abstract D.E.J.) "The author has introduced certain alterations into the method previously used by him for obtaining aluminium by electrolysis. The effect of these improvements has been to diminish the difference of potential required, and to increase the yield, so that 32 grms. of metal are now obtained by an expenditure of energy equivalent to one horse-power hour. The "horse-power" referred to by the author is the French (*cheval-vapeur*), which is less by about 1.3 per cent. than the English horse-power.

The bath is made up in the same way as before. The vat is a casting of the same form as that previously employed, but its dimensions are smaller and the arrangement of the electrodes is altered. The inside of the vat is lined with a layer of agglomerated carbon, which serves as the *negative* electrode. The aluminum is deposited on this lining, and collects at the bottom of the vessel. The apparatus can be used continuously for

a period of 30 days. The following are the details of a day's work with a single vat (one of three arranged in series):

Density of current (per square centimetre):—At the positive pole = 0.75 ampère, at the negative pole 0.5 ampère.

Temperature — 920° C.

Duration of experiment, t, — 22 hours.

Strength of current, C, — 1,500 ampères.

Quantity of electricity, C t — 33,000 ampère-hours.

Theoretical weight, W — C t × 0.34 — 11,200 grammes.

Weight obtained, w, — 6,500 grammes.

Efficiency of system in terms of quantity of electricity used } — $\frac{w}{W}$ — 58 per cent.

Minimum electro-motive force, e — 2 volts.

Resistance of the electrolyte, r — 0.0017 ohm.

Difference of potential at the electrodes, E — e + C r — 4.55 volts.

Power employed, P — $\frac{C\,E}{736}$ —9.27 horse-power.

Total expenditure of energy — P t — 204 horse-power hours.

Weight of metal obtained per horse-power hour — 31.9 grammes.

Expenditure of energy per kilogramme of aluminium obtained — 31.3 horse-power hours.

These results are an improvement on those previously obtained and the manipulations are also simpler.

When commercial alumina is used and transformed directly into aluminum oxyfluoride (without previous purification) for feeding the bath, the metal obtained contains from 2 to 3 per cent. of impurities, mainly silicon ; the proportion of iron is only 0.6 to 0.8 per cent. As usual the aluminium can be hammered and worked cold. With products free from silicon, the richness of the metal rises to 99 per cent. The author believes that the necessary difference of potential may be further reduced to 4 volts (independently of the current strength). With this difference of potential the sodium chloride (which forms 65 per cent. of the bath), would no longer be decomposed, for the electro-motive force required for its decomposition is 4.35 volts ; consequently the yield (or efficiency) would rise to 70 per cent. The outstanding loss of 30 per cent. appears to be mainly due to the action of the nascent aluminum, which probably attacks the fluoride and forms a sub-fluoride. In fact, the yield increases when the proportion of fluoride in the bath is diminished by dilution. The losses are greatly diminished and the yield nearly reaches the theoretical amount when the apparatus is used for obtaining alloys of aluminum. In this case the inside lining of the vat is dispensed with. The vat itself is made of one of the metals forming the alloy, and the aluminum in the nascent state unites with it."

THE AMERICAN RAILWAY MASTER MECHANICS ASSOCIATION SCHOLARSHIPS.

BELOW are given the replies received by the *American Journal of Railway Appliances*, in response to a circular letter sent to leading members of the Association requesting their opinion regarding the best course of training necessary to educate young men to be master mechanics.

President Morton was at the same time requested to give information about the Institute's course with special reference to its bearing upon railroading.

President Morton's reply was as follows:

HOBOKEN, N. J., September 19, 1891.

Editor Journal of Railway Appliances:

In reply to your letter of the 8th, I would say, that I believe our course to be exactly fitted to the requirements of one aspiring to the position of master mechanic or superintendent of motive power on our railroads.

This assertion is supported in the best way according to the proverb as to "the proof of the pudding," by the fact that at the present time at least seven of our graduates occupy such positions in some of the best known railways, such as the Pennsylvania, the Central, the Chicago, Burlington & Quincy, and the like. The reason why this number is not much larger is easily stated.

Railroad managers, as a rule, require all young men entering their service from technical schools or elsewhere, to begin work as apprentices, under conditions which make the position anything but attractive to young men of capacity and education.

Our graduates for many years have been in such demand for much more agreeable and lucrative positions that only in exceptional cases have they entered the service of railroads, but where they have done so their success in the course of time has been most satisfactory.

It would take much time and space to give anything like a detailed synopsis of our course, but I may say that it covers closely

all that is involved in the designing of machinery, and the construction and running of the same, including extended courses in the mathematics necessary for all calculations, mechanical drawing, the principles of construction, workshop practice with all ordinary machine tools, foundry work, and experimental courses in the running and testing of steam and gas engines, pumps, injectors and so forth.

Forty-four pages of our catalogue are devoted to the description of our course, and any one desiring this can receive it on application.

For the last seven years the number of applicants for admission has so far exceeded our accommodations that our entrance examinations have been competitive. Very truly yours,

HENRY MORTON,
President Stevens Institute of Technology.

Among the replies to the circular letter were the following:

RICHMOND, VA., September 14, 1891.

Editor Journal of Railway Appliances:

In reply to yours of the 27th ult. on the subject of the education necessary for a young man entering on a mechanical course, I would say that he should have a thorough course of mathematics, mechanical drawing and chemistry. WM. GARSTANG,
Superintendent Motive Power, Chesapeake & Ohio Ry.

Editor Journal of Railway Appliances:

Answering your favor of the 26th ult. on the subject of "What education is most needed to most efficiently prepare a young man for work in the master mechanic's department," will say that as it was not my good fortune to have received a technological education, I fear that anything which I could say on this subject would be the purest theory, as I can only speak of the position as I am able to see it from the circumscribed position of one who has only received a common school education. I can conceive of no higher educational ability that could be utilized by a master mechanic than that required of a candidate for admission to a scholarship, as set forth in the circular of the Association of August 15th on this subject. My highest conception of a master mechanic is a man who is possessed of this knowledge combined with a practical experience as a machinist and a locomotive engineer. The many intricate

details connected with chemical and physical tests and analysis are questions of abstract science which are accessible to any thoughtful man, and are embraced in the knowledge possessed by the chemist, the metallurgist and the prudent and thoughtful manufacturer.

You ask, "What would you tell a young man who asked your advice as to the training necessary to prepare him for the work in the master mechanic's department."

I should say: First, you must be a student. This world is a school, life is a constant study and recitation. Be sure you acquire the fundamental rules, for your school days are simply to teach you *how to study*. Do not burden your mind with Latin, French, physics, rhetoric, univeral history, etc., except as a recreation. Make mathematics and dynamics your favorite study, acquire a thorough knowledge and, if possible, a skill in draughting. Secure the following mechanical books: Thurston's Growth of the Steam Engine, Forney's Catechism, Sinclair's Book on the Locomotive, Appleton's Cyclopedia of Applied Mechanics and Appleton on Shop Practices. These, together with Nystrum's or Haswell's Hand Book on Mechanics and Engineering, will supply a fund of information that the most zealous student will not be able to exhaust. Above all keep pace with the progress of the arts by perusing the leading mechanical papers. In our time the evolution in mechanics is very rapid, the practices which are considered perfect to-day in a short time are declared obsolete. Train your mind to look for progress and improved methods, which you are as liable to see developed in the apprentice and laborer as in the skilled mechanic. The education that will insure the greatest concentration of thought and expansion of ideas is the course required. It may be necessary to introduce a good deal of irrelevant information to accomplish this. We will allow the educator to decide this.

Yours truly,

W. H. LEWIS,

Master Mechanic, Chicago, Burlington & Northern Railroad.

Editor Journal of Railway Appliances:

Noting your letter of August 27, I should say that the first requisite for a young man to become a student in a technical school is to have education sufficient to enable him to pass the required examination for admission.

This should be supplemented by all the practical experience that a boy can get in machine work shop. It will be found that knowledge of using tools and iron working machinery will be of great value to the student in his studies. Yours truly,

J. N. LAUDER,
Supt. Rolling Stock, Old Colony Railroad Co.

Editor Journal of Railway Appliances:

In answer to yours about master mechanics' sons' scholarship, I would say:

First.—He should have a good common education; then at the age of fifteen he should be put into the workshops—hard work and no favors.

Second.—He then should have two years in the drawing office. Part of this time he should have sketching and estimates given him.

Third.—He should then be sent to this college for the scholarship. The branches that I think most important would be mathematics and chemistry. With the above, if the young man has the capacity to sustain himself in his mechanical undertakings, such as command of men, discerning right from wrong, and talent to block out new work, he will make a good master mechanic.

Yours truly,
EDWARD MAY,
Master Mechanic Intercolonial Railway of Canada.

THE BOARD OF TRUSTEES.

THE Board of Trustees of the Institute is now a body of nine members. The five newly elected members are:

Mr. Andrew Carnegie, of Pittsburg, Pa.

Mr. Charles MacDonald, C.E., of New York.

Chancellor Alex. T. McGill, of New Jersey.

Col. Edwin A. Stevens, of New Jersey.

Mr. Alex. C. Humphreys, M.E., of New Jersey.

The old members are Mrs. M. B. Stevens, Mr. S. B. Dod, President Henry Morton, Ph. D., and Mr. Wm. Kent, M. E.

The Board, as originally constituted, consisted of Mrs. M. B. Stevens, Mr. Wm. W. Shippen and Mr. S. B. Dod. No change occurred in the membership for sixteen years, until 1886, when the death of Mr. Wm. W. Shippen caused a vacancy, which President Morton was elected to fill.

The following year the Alumni Association applied for, and was given, a representation in the Board.

The manner of selecting the Alumnus Trustee was, at the time, explained in the INDICATOR and, as is known, Mr. A. P. Trautwein, M. E., '76, was elected to serve until 1890, when his term expired, and he being ineligible for immediate re-election, Mr. Wm. Kent, M.E., '76, succeeded him.

These comprise all the changes that have occurred in the Board during the first twenty-one years of the Institute's existence. During this period the growth of the Institution has been a steady and healthy one, although somewhat retarded by the limited resources at command. Indeed, the growth has been so rapid within the last few years, that the accommodations of the buildings will be inadequate to meet the requirements of classes larger than those now entered. As the number of applicants are increasing each year, the question of providing additional accommodations is

now an urgent one and will, undoubtedly, be the first to receive the attention of the new Board of Trustees.

It may be of interest here to know the provisions of the bequest made by Mr. Edwin A. Stevens to establish an Institution of Learning, and we, therefore, reprint from the earlier Institute catalogues the portion of the will relating to this bequest :

"And I do further give, devise, and bequeath to my said wife, Martha B. Stevens, William W. Shippen, and Samuel B. Dod, and to their heirs and assigns forever, to hold as joint tenants, and not as tenants in common, in trust, as hereinafter mentioned, all that block of land in Hoboken bounded by Hudson Street, River Street, and Fifth and Sixth Streets (excepting such interests therein, if any, as I may not own at my death), and one hundred and fifty thousand dollars in the stocks and bonds of the Morris and Essex Railroad Company, reckoning the same at par—that is to say, one-half of that sum in the first mortgage bonds of said company, and one-half in the said stock.

"I direct and empower the acting trustees or trustee under this trust (whether the original trustees herein named or the survivors or survivor of them, or his, her, or their successor or successors), at any time or times when one or two shall be dead or have ceased to act, to appoint one or two new trustees in his, or her, or their stead who shall have died or ceased to act; and by advice of counsel my trustee or trustees in whom the legal title shall be vested shall convey, assure to, and vest in said three trustees (the appointing as well as the new trustee or trustees) the said trust property in fee simple as joint tenants, and not as tenants in common, in trust. And this trust is this: that upon said land, at such time as the acting trustee or trustees shall think proper—certainly within two years after my death—he, she, or they shall, out of the proceeds of said personal property (to be procured by sale or other prudent disposition, investment, use, or appropriation thereof, in the discretion of the trustee or trustees for the time being), erect, of some substantial but economical material, as substantial and economical as trap rock, a plain building or buildings, suitable for the uses of an Institution of Learning, which I direct my acting trustee or trustees for the time being out of the means herein provided, and such as shall proceed therefrom, with all convenient speed, and within three years after my decease, to establish there—employing, paying, and discharging at his, her, or their discretion the officers, and tutors, and servants thereof—and forever to manage and control at his, her, or their discretion, but for the benefit, tuition, and advancement in learning of the youth residing, from time to time hereafter, within the State of New Jersey; but my said acting trustee or trustees shall, from time to time, decide who of said youth shall receive the benefit thereof, and direct the tuition in said Institution; and make all proper by-laws, rules and regulations for the management of the officers, tutors, servants and scholars connected with said Institution.

"*The tuition is not to be wholly free, unless to such youth as said acting trustee or trustees shall direct; nor is it my intention that the cost of tuition of any youth shall be wholly paid by him or her. The proportion of payment by each youth I leave to the discretion of the acting trustee or trustees.* It is my intention that the Institution hereby directed and created shall be perpetual, and that the above-mentioned original trustees and their successors shall forever continue and be the governors thereof, and have the superintendence of the same; and it is my will and desire that, if it cannot be legally done according to my above intention by them without an Act of the Legislature of the State of New Jersey, they will, as soon as possible, and certainly within three years after my decease, apply for an Act of the Legislature to incorporate them for the purpose above specified, and to effectually provide for the establishment and maintenance of said Institution with the means which I have devoted by this, my will and testament, to the said purpose; and I do further declare it to be my will and intention that the said real and personal property hereinbefore and hereinafter devised and bequeathed to my said trustees for said purposes shall, at all events, be applied for the uses and purposes above set forth; and it is my desire that all courts of law and equity will so construe this, my will, as to have the said property, real and personal, appropriated to the above uses, and that the same shall, in no case, for want of legal form or otherwise, be so construed as that my relations, heirs, devisees, or legatees, or any other persons, shall inherit, take, possess, or enjoy said real and personal property hereinbefore and hereinafter devised and bequeathed for said purposes, except in the manner and for the uses hereinabove specified.

"I do, also, out of the said last-mentioned residue of my estate (excluding Castle Point and the homestead lot, and the houses thereon) remaining after the payment of my debts, the said eight hundred thousand dollars in legacies, and the appropriation of so much of my estate as is necessary to answer the before-mentioned charitable bequests and devises, and the appropriation for the steam battery, give, devise, and bequeath to my said trustees of said Institution of Learning, and direct my executors to pay to them within five years after my decease, such sum of money, not exceeding five hundred thousand dollars, as the said trustees of said Institution of Learning, in their discretion, shall think necessary, to be set apart, invested, and appropriated to and for the purpose of forever maintaining the said Institution of Learning, for the purpose before described, so that the same be liberally maintained out of the income and interest of such sum, and said sum of money, and the interest and income thereof, shall be subject to all the trust hereinbefore declared with respect to the said Institution of Learning, and the property appropriated hereinbefore for the erection, maintenance, and establishment thereof; and I do, with reference to the said sum, and interest and income thereof, declare my desire and intention to be the same as I have before fully expressed with reference to the property before devised and bequeathed for the same purposes."

The following is the enacting clause of the articles of incorporation of the Stevens Institute of Technology:

"*First.—Be it enacted, by the Senate and General Assembly of the State of New Jersey*, That Martha B. Stevens, William W. Shippen, and Samuel B. Dod, and their successors, shall be, and they are hereby constituted a body politic and corporate, by the name of 'The Trustees of the Stevens Institute of Technology,' and by that name shall have perpetual succession, according to the provisions of said codicil, and may sue and be sued, implead and be impleaded, and may purchase and hold property, whether acquired by purchase, gift, or devise, and whether real, personal, or mixed, and may make and have a corporate seal, and the same break and alter at their pleasure, and shall have all other rights belonging to similar corporations by the laws of this State.

Second.—And be it enacted, That the entire management of the affairs and concerns of the said corporation, and all the corporate powers hereby granted, shall be and hereby are vested in the above-mentioned trustees, to manage and control the same, as in said codicil provided.

Third.—And be it enacted, That the trustees shall have power from time to time to enact by-laws, not repugnant to the Constitution or laws of the United States, or of this State, or to this Act, for the regulation and management of the said corporation or institution of learning; to fill up vacancies in the Board, and to prescribe the number and description, the duties and powers of the officers, the manner of their appointment and the term of their office, as in said codicil directed and empowered to do.

"*Fourth.—And be it enacted*, That for the purpose of carrying out the object of this Act, the said corporation shall have power, from time to time, to purchase, take, and hold real and personal estate, and to sell, lease and dispose of the same; provided, that nothing in this Act contained shall empower the said corporation to sell, lease or dispose of that block of land in Hoboken bounded by Hudson Street, River Street, and Fifth and Sixth Streets, if at any time the title to the same shall become vested in the said corporation.

"*Fifth.—And be it enacted*, That the said corporation shall have and possess the right and power of conferring the usual degrees appropriate to a school of technology.

"*Sixth.—And be it enacted*, That this Act shall take effect immediately.

"Approved February 15, 1870."

From the above it will be seen that in addition to the plot of ground upon which the Institute buildings now stand, the trustees had at their disposal the sum of $650,000.

After defraying the cost of the building and its equipment out of this sum, the balance amounting to about $400,000 was invested in various securities and is a permanent source of income.

Strange as it may seem, it is nevertheless true that during a period of nearly twenty years following its establishment, the Institute has not been in receipt of a single bequest, although the endowment of small institutions, with limited fields of usefulness, has been a matter of frequent occurrence.

Fortunately, the Institute was not without its benefactor when its development required that certain improvements should be made. We have reference to the enlargement and equipping of the work-shops, for which purpose President Morton donated, in 1880, the sum of $10,000, and the establishment, in 1886, of the Department of Applied Electricity, towards which he contributed about $3,000, which sum was applied in the equipment of the electrical laboratory and in maintaining the Department until such time as the resources of the Institute were sufficient to support it. And when, in 1888, the importance of establishing the Chair of Engineering Practice was recognized, President Morton again supplied the funds to endow this Chair, and as a first installment, donated $10,000, which sum will be increased as occasion requires.

Considering that the newly elected members of the Board of Trustees are men of large experience and influence, alumni will, no doubt, welcome the election of a larger Board at this time as a most auspicious event in the Institute's history.

ATHLETICS.

THE foot-ball season has come and gone. It has not brought us that success for which we hoped early in the season. Defeat, in fact, has been much more common than victory, and in the League we have been forced to take last place. All this is irritating, and men are very prone to grumble and wonder why Stevens can't put up as good a team as the next college. But these persons forget the great development of the game during the last five or six years, and especially the rapid advance in the style of playing of the smaller colleges. So intricate has the game become now-a-days, that the men must first be trained individually in the "principles of the game," and then together, for weeks, to develop the proper "team work." All this can be done in colleges like Williams, or Amherst, where the students do not have to work so hard as here, and have, moreover, the advantages of dormitories, and good campuses. The advantages conferred by these things is apparent (in its results), to the most casual observer, in the greater endurance of the players, quickness of play, and development of team work, especially in the way of tricks, and handling of the rush line. Taking into consideration these disadvantages, and also the fact that Stevens was represented by a remarkably light team, the record of the team appears in a different aspect. The great trouble in all the games has been to stop the enemy's rushes through the center. Just at present the prospect of getting heavy men to fill these positions is rather poor, but it is to be sincerely hoped that Captain Coyne will succeed in finding them.

The Foot-ball League seems at present pretty thoroughly broken up. The last meeting was held at the Parker House, Boston, December 14, 1891. Stevens was unable to send delegates, on account of the examinations then in progress. A dispute soon arose between Williams and Amherst about the championship, both colleges having the same per cent. As Dartmouth sided with Williams, and Technology with Amherst, the result was a deadlock, which broke up the meeting. No officers were elected, which amounts, practically, to a dissolution of the Association. The outcome of this, it is thought, will be the formation of a triangular league between Williams, Amherst and Dartmouth. Stevens and Technology will then be left to form a new league. Plans have already been discussed for forming a league of Technology, Stevens, Brown, Trinity and Rutgers. These five would make a strong league, would possess the advantage of being more accessible, and bring in, for Stevens at least, the important factor of local rivalry, which is missing in the Association.

The prospects are very good for a first-class lacrosse team this spring. All of last year's players are back, with the exception of Smith, Atwater, and Howell, so that Martin will have a very strong body of players from which to select his team. A plan is on foot to secure the use of the armory for indoor practice, and as soon as possible regular work will be begun

in the field. The game has been steadily gaining in popularity, and the teams in this neighborhood are stronger than ever before. There is also the probability that the University of Pennsylvania will join the college league in the spring. This would go far to make up for the loss caused by Princeton's withdrawal.

At this point the INDICATOR wants to remind the students that the Athletic Association needs the support, moral and financial, of each one of them. The Association is poor. It needs money, and needs it badly. The balance on hand is only $60.00, and there is no source of further revenue in sight. To carry the lacross team through the season, at least $125 more is needed, and unless the amount can be made up by dues from *new* members, the Association will be obliged to fall back upon a subscription from the college.

The championship series of the New England Intercollegiate Football Association resulted as follows:

Oct. 31, Williams *vs.* Stevens, Williamstown, 60–0.
" 31, Amherst *vs.* Technology, Boston, 24–14.
Nov. 4, Stevens *vs.* Dartmouth, Hoboken, 12–32.
" 7, Williams *vs.* Technology, Williamstown, 30–0,
" 7, Amherst *vs.* Dartmouth, Hanover, 14–14.
" 14, Williams *vs.* Dartmouth, Hanover, 14–6.
" 14, Stevens *vs.* Amherst, Amherst, 0–38.
" 20, Williams *vs.* Amherst, Amherst, 0–0.
" 21, Dartmouth *vs.* Technology, Boston, 8–6.
" 26, Stevens *vs.* Technology, Hoboken, 0–16.

As will be seen the order of the teams is Williams, Dartmouth, Amherst, Technology, and Stevens.

Other games played by the team were:

Oct. 5, Stevens *vs.* N. Y. A. C., Hoboken, 6–5.
" 10, " " N. Y. U., Hoboken, 38–0.
" 17, " " Cornell, Ithaca, 0–72.
" 21, " " Columbia, Hoboken, 52–0.
" 24, " " Rutgers, New Brunswick, 10–12.
Nov. 7, " " West Point, West Point, 12–14.
" 23, Freshman–Sophomore Game (95–94), 12–18.

Of the Williams game but little can be said. The score tells the story. Williams had a fine team, entirely outclassing Stevens, and her team work was good all the way through. Our men labored under one disadvantage, however—that of playing on the same day they went up. To such practice does financial stringency force us.

The Dartmouth game showed a marked improvement, but still it was painfully apparent that Stevens lacked that "dash" and quickness of lining up and putting the ball in play which characterized Dartmouth's playing. Quick playing is especially effective against a team which is accustomed to line up slowly, and almost invaluable in the case of a light team like ours, where fast playing must make up for lack of weight.

The game with Amherst, however, showed a falling off. Amherst played a fumbling game, but Stevens seemed unable to take any advantage of this circumstance.

The last game—with Technology—was rather a disappointment, as hopes were cherished of winning the game. Technology's men, however, were too heavy, and too well trained. The game, though, will be remembered for one thing—that is, the whirligig, a sort of revolving "V" trick, never seen here before, and which proved very effective whenever it was necessary to gain a few yards.

Turning to the practice games, there is a brighter prospect, as here victory is mingled with defeat. The N. Y. A. C. game was the first of the season, and of course not remarkable for fine playing. The game with N. Y. U. proved a "walk-over," as also did that with Columbia (much to their surprise). The large score which Cornell piled up against us was rather a surprise, but looked at in the light of her subsequent showing against Princeton, it can be easily explained.

The games with Rutgers and the West Point Cadets were two of the best played and most exciting of the season. At Rutgers the team suffered from the absence of its heaviest center men, being unable to hold Rutgers' rushes through the center, while they, on the other hand, could not prevent Stevens from running the ends. It is a pity that the return game could not have been played, for on the home grounds we could undoubtedly have evened matters.

The West Point trip will be long remembered. A jolly party of one hundred and fifteen; special cars; a perfect day; cordial and gentlemanly treatment from the cadets; and an exciting game, in one of the loveliest spots on earth, made up an experience too enjoyable not to be repeated again this year. Stevens brought up a light team only to find that she had underestimated the strength of her opponents, and that she could not hold her centre during the second half. Maynard and Mackenzie ran finely around the ends, and had Stevens put her heavier men in centre, she could have won easily. However, wait till next time!

The Freshman-Sophomore game proved intensely exciting. The Sophomore's labored hard to wipe out the sting of losing the rush, and their efforts were crowned with success. '95's team was superior individually, but the superior team-work which Capt. Coyne drilled into his men, aided by the magnificent running and tackling of Maynard, won the game for '94.

Frank Coyne, Captain of the Sophmore team last fall, and end rush on the University, has been elected Captain of the University Football Team for '92. Capt. Coyne has taken a long look ahead, and, seeing that there is no prospect of much new material in '96, has already begun to develop that on hand.

About thirty men have reported for regular work in the gymnasium, which will be continued, under proper direction, during the winter.

It is rumored that the base-ball men are not satisfied with the decision of the Athletic Association, to drop the game this spring, and will try to

raise enough money to put a team in the field. THE INDICATOR wishes them all success. The only motive for dropping the team was lack of money to support it. If that can be remedied, let us have a base-ball team, by all means.

The annual meeting of the Athletic Association was held on January 12. Officers for the coming year were elected as follows: President, Hermann F. Cuntz, '93; Vice-President, George B. Fielder, '94; Secretary, Arthur E. Merkel, '93; Treasurer, Henry D. Lawton, '94; Executive Board, W. P. Mackenzie, '93; R. E. Hall, '94, and W. H. Corbett, '95.

The Treasurer handed in a report, showing a balance of only $62 on hand. This made it evident that the Association could support but one team in the field the coming season. After a lively discussion it was decided to withhold financial support from the base-ball team for this season, substituting for the University team, a series of interclass matches. Mr. McGahie, Editor-in-Chief of *Life*, announced on behalf of that paper that in order to encourage the development of new material, *Life* would present a medal to that lacrosse player, from the Freshman Class, who should show the greatest improvement in his work. Decision to be left to three older members of the team. He also announced that if the custom were found to work well, it would probably be continued by succeeding boards.

TREASURER'S REPORT.

THE STEVENS INSTITUTE ATHLETIC ASSOCIATION IN ACCOUNT WITH HERMANN F. CUNTZ, TREASURER.

Dr.		*Cr.*	
To Balance on hand, July 1, '91	$206.73	By '91-'92 Membership Tickets, Boehm Bros	$1.75
" Initiation Fees, 36 @ $2	72.00	" Photos, '92's Foot-ball Team	1.50
" Dues, 97 Members @ $3	288.75	" W. O. Ludlow, Expenses to I. Tennis Tournament	15.00
" Locker Rentals	3.25	" 1 Doz. Base-ball Photos	18.00
" 5 Base-ball Photos @ $1.50	7.50	" Sundries	1.00
" Gate Receipts, N. Y. A. C. Game.	12.00	" Foot-ball Team (suits)	87.45
" " " N. Y. U. Game, less Guarantee	20.00	" " " " (sweaters)	46.80
" Gate Receipts, Columbia Game.	20.60	" " " " (sundries)	30.00
" Guarantee, Cornell Game	188 00	" " " " Rutgers trip, etc	50 00
" Gate Receipts, '94-'95 Game	20 40	" Foot-ball Team, Cornell trip	190 00
" " "	2.75	" " " " Rutgers trip, etc	30.00
" Union Athletic Club for use of grounds	5.00	" Foot-ball Team	220.00
" Foot-ball Management, cost of sweaters	46.80	" " " "	110.00
		" T. Smithson, work on grounds.	25.00
		" Foot-ball Management for '92	5.00
			$831.50
		Balance, January 14, '92	62.28
	$803.78		$893.78

INSTITUTE NOTES.

AT THE MEETING OF THE FACULTY, at the close of the first term, action was taken in reference to students deficient in the subjects taken up in the earlier part of the course.

In consideration of the fact, that the passing of an examination is merely evidence that a student is proficient in the subject at the time of the examination, and as the majority of subjects taught are preparatory to others, it is deemed necessary that they should be kept in mind and reviewed from time to time, or as they are needed, in subsequent work.

If, therefore, any student shows such a marked deficiency in previous work as to seriously interfere with his progress, he may, after a month's notice, be re-examined in the main points of that subject.

A resolution providing for such re-examinations to be made with the approval of the President, was adopted by the faculty, and will be published in the next issue of the catalogue.

MANY OF THE APPLICANTS for admission to the Institute have been found seriously deficient in the English subjects, more particularly in spelling, punctuation and style in composition.

An announcement will be made, hereafter, in the catalogue, stating that such deficiency may cause the rejection of applicants.

The Engineering Magazine for December, 1891, begins the publication of a series of papers entitled "American Supremacy in Applied Mechanics," by Professor Coleman Sellers, E. D. In announcing the publication of these papers, *The Engineering Magazine* says, "Professor Sellers is a mechanical and civil engineer of very distinguished attainments, who has devoted a lifetime to the study and practice of every branch of applied mechanics, and, having spent much time abroad, in the enjoyment of the most influential acquaintance, his opportunities for observation and comparison of European and American methods have been unlimited. Indeed, no living American is more fully or admirably equipped than he to speak authoritatively upon this all-important subject."

A REPORT ON "Trap Siphonage and Trap Seal Protection," prepared by Prof. Denton, contains the results of experiments conducted by him at the Institute for the purpose of determining the degree of reliability to be attached to the several methods and means of preserving the trap seals now known in plumbing practice, and also as to the relative capacity of those seals.

The report, which is published in full in Vol. XV. of the Transactions of the American Public Health Association, has been very favorably noticed by many of the trade journals.

PROF. WOOD presented a paper on a "Test of a Pulsometer," at the New York meeting of the American Society of Mechanical Engineers.

PROF. JACOBUS has been elected a member of the New York Mathematical Society.

A COMPLETE CORLISS ENGINE MODEL has recently been added to the apparatus used for instruction purposes in the Department of Experimental Mechanics. The model illustrates clearly the peculiar trip motion of the valve gear of the Corliss engine.

AT A MEETING OF THE American Chemical Society, held December 29th, in New York City, Dr. Leeds was elected one of the four Vice-Presidents of the society. Dr. Stillman was elected one of the three Curators, and Durand Woodman, '80, Secretary. At this meeting Dr. Leeds read a paper on the "Properties of Matter as Periodic Functions of the Atomic Weight."

THE ANNUAL REPORT of the State Dairy Commissioner will contain an article by Dr. Leeds on "The Preservation of Milk."

A RECENT ENGLISH PUBLICATION, "Engineering Chemistry," by H. Joshua Phillips, F. I. C., F. C. S., quotes Dr. Stillman on the Analysis of Boiler Incrustations, and contains his scheme for Water Analysis, which appeared in the INDICATOR, Vol. VII., No. 4. "Engineering Chemistry" is a practical treatise for the use of analytical chemists, engineers, iron-masters, iron founders, students, and others; it will probably be used as a reference book for the Junior Class in the analysis of fuels and heating gases.

Some of the analyses by Dr. Stillman, referred to in this book, have also appeared in the "London Chemical News," "Dingler's Polytechnic Journal," "Chemische Central-Blatt," edited by Prof. Dr. Rudolf Arendt, and also in the "Journal of Analytical and Applied Chemistry."

PROFESSOR MENDENHALL, of the U. S. Coast Survey, spent several days of November in taking observations at the Institute, for the determination of the force of gravity. A new kind of pendulum was used in the experiments. Prof. Pierce, Major Hershell of England, and other scientists, having previously made essentially similar experiments, in the basement of the building, Stevens Institute has become a standard station for such observations.

A COPY OF THE specimen examinations papers of the Institute was sent to each member of the American Railway Master Mechanics Association, about December 1, and accompanying it was a statement by the Secretary calling attention to the fact that only one of the four scholarships owned by the Association was then filled, and giving as a reason for the scarcity of applicants the rigid preliminary examination required for entrance to the Institute.

The Secretary recommended the attendance, for one year, at the Stevens School, to those who desire to prepare themselves for the Institute, or other similar scientific institutions.

REUNION OF THE CLASS OF '76.—The quinquennial reunion of the Class of '76 was held at the House of the Engineers' Club, 10 West 29th Street, New York City, on Thursday evening, November 19th, 1891.

The members present were: Jas. M. Cremer, Gus. C. Henning, William Kent, Joseph Kingsland, A. Riesenberger, Alfred P. Trautwein and Alfred R. Wolff.

Distant location precluded the attendance of nearly all of the eight absent members. They remembered the occasion, however, by sending hearty greetings.

It was decided to hold a reunion of the class annually hereafter, which is to occur at the time of the New York meeting of the American Society of Mechanical Engineers.

THE STEVENS SOCIAL SOCIETY held their annual meeting for the election of officers on Wednesday, January 6th. A. J. Post was made President; W. B. Field, Vice-President; Morgan E. Craft, Secretary; and W. P. Mackenzie, Treasurer. The President subsequently appointed Miller, '92, MacDonald and Mackenzie, '93, a committee to arrange for the first dance of the season. The newly elected members are: Patterson, Litchfield, Atkins, Reed, '92, Braine, Boody, Griswold, Huppertz, '93, Kollstede, R. P. Hamilton, Anderson, '94, Raoul, Willett, Paulding, Hamilton, Cuming, Smart, Barnum, '95.

MR. HAWKRIDGE is at present making various instruments and devices to illustrate some of the principles and laws in physics. These instruments, sketches of which are frequently found in text-books, are seldom seen in actual operation. When completed, Prof. Morton will probably use some of this apparatus in his lectures.

THE JUNIOR BALL COMMITTEE for 1892 is Alvin Boody, Bancroft G. Braine, Morgan E. Craft, Harold E. Griswold, G. Lloyd Wall and Edward A. Huppertz. The proposition to hold the ball during the second, or at the beginning of the third term, met with some favor, but it has been again decided to make the ball an event of Commencement Week. As Sherry's charming ball rooms can no longer be secured for college dances, the Committee is having considerable difficulty in selecting a ball room which, as regards location as well as appointment and size, will give general satisfaction.

THE '93 CLASS DINNER COMMITTEE consists of W. P. Mackenzie, J. F. Paulsen, A. B. Lord, C. T. Bayless and W. B. Axford.

STEVENS ENGINEERING SOCIETY elected Mors O. Slocum, Treasurer; an Executive Committee consisting of Cuntz, '92, Chandler, '93, and Martin, '92, Mackenzie, '93, W. A. Waefelaer, '92, Macdonald, '93, and a large number of new members, namely, 12 Seniors and 19 Juniors. Two meetings were held during the Fall Term. At the first, on November 21st, Wm. E. Strong read an interesting and entertaining paper on the "Zalinski Dynamite Gun," and H. Reed, an instructive paper on "Underground Construction for Electrical Purposes."

The meeting of December 4 was particularly good, owing to the excellent themes brought before the members. They were: "The Hudson River Tunnel," by Kingsley L. Martin, and "Development of Shipbuilding in America," by Henry D. King.

THE BANJO AND GUITAR CLUB made its first appearance at Messrs. Brooks and Dentaur Concert, at Lenox Lyceum, on January 9. They helped to make up the orchestra of a hundred banjos. The members for this year are: 1st Banjos: A. J. Post (Leader), Wettlaufer, '92; Barnum, '95; Maynard, '94. 2d Banjos: Griswold, '93; Cook, '93; Mathey, '94. Guitars: Shepard, '92; Coleman, '94; Parker, '93; Shoemaker, '94, Messemer, '96.

THE GLEE CLUB has been reorganized, and promises to make a creditable record. The members are: 1st Tenors: Kollstede, '94; Church, '94; King, '92; Pierson, '94. 2d Tenors: Crowell, '94; Litchfield, '92; Coleman, '94; R. Messemer, '96. 1st Base: Ludlow, '92; Daly, '96; Hill, '92; Woolsey, '95; H. Messemer, '96. 2d Base: Smith, '94; Hodgeman, '94; Craft, '93; Field, '94; Hall, '94. The officers for the year are: W. B. Field, President; N. S. Hill, Manager, and R. E. Hall, Secretary and Treasurer.

The two clubs will give a concert on the second Thursday in February, and an Easter Tour is being discussed.

INSTITUTE PERSONALS.

ALEX. C. HUMPHREYS, '81, JOHN M. RUSBY and ROLLIN NORRIS, '85, and C. R. COLLINS, '86, attended the New York meeting of the American Gas Light Association last October.

THE FOLLOWING STEVENS ALUMNI were in attendance at the New York meeting of the American Society of Mechanical Engineers in November, 1891: J. E. Denton, '75; G. C. Henning, Wm. Kent, A. Riesenberger, '76; F. E. Idell, L. H. Nash, '77; Geo. M. Bond, '80; Alex. C. Humphreys, Albert Spies, E. S. Cronise, '81; Hosea Webster, Chas. W. Scribner, '82; Jas. E. Sague, '83; Chas. W. Thomas, Wm. L. Lyall, D. S. Jacobus, Wm. H. Bristol, C. A. Carr, H. de B. Parsons, '84, R. H. Rice, John M. Rusby, '85, H. A. Bang, Geo. Dinkel, Jr., Paul Doty, '88.

'75.

SAMUEL D. GRAYDON and WM. W. DASHIELL are associated in business as experts on questions of lubrication, and have their office at 41 Dey Street, New York City.

'76.

WM. KENT contributed an article on "The Influence of Steam Jackets," to *Cassier's Magazine* of December, 1891. A paper on the same subject was presented by Mr. Kent at the New York meeting of the American Society of Mechanical Engineers.

'77.

LEWIS H. NASH, Designing Engineer of the National Meter Company Brooklyn, N. Y., was elected in November, 1891, to membership in the American Society of Mechanical Engineers.

'79.

J. H. LONGSTREET is located at 300 and 302 Chestnut Street, Philadelphia, Pa. Longstreet & Whitelaw are the agents for the National Water Purifying Company.

'81.

ALBERT SPIES has resigned his position as associate editor of *The Engineering Record* and has established an office as consulting engineer at 136 Liberty Street, New York City.

ERNEST S. CRONISE has been elected a member of the American Society of Mechanical Engineers. Mr. Cronise is now in charge of the Meter Department of H. R. Worthington, 86 Liberty St., New York City.

'83.

E. DUQUE ESTRADA was married to Isabel Arnold Reynolds, niece of Mr. and Mrs. Robert P. Crawford, on Wednesday, December 9, 1891, at Fairfield, Pa.

'84.

W. S. ALDRICH, Associate in Mechanical Engineering, in Department of Electrical Engineering, Johns Hopkins University, Baltimore, Md., presented two papers on "Notes on Electro-Magnetic Machinery," to the Electrical Section of the Franklin Institute, December 1, 1891, and January 5, 1892.

EDWARD P. THOMPSON is the author of an interesting and valuable little book, entitled "How to Make Inventions, or Inventing as a Science and an Art."

The book, which is dedicated to his alma mater, is published by the D. Van Nostrand Company, 23 Murray Street, New York City. In presenting a copy of the book to the Institute Library, Mr. Thompson stated that as he was prepared to write it from the instruction received at the Institute, he took the liberty and pleasure of dedicating it to the Institute

'85.

W. N. STEVENS, of the firm of Algee, Stevens & Co., Manufacturers Agents Railway Supplies, is located at 43 Forsyth Street, Atlanta, Ga.

ROLLIN NORRIS read a paper on the "Theoretical Effect of Pre-Heating Blast Steam and Oil in Water Gas Manufacture," at the 19th Annual Meeting of the American Gas Light Association, held at New York last October. The paper was published in the *American Gas Light Journal* of November 31, 1891.

THE INDICATOR has not been able to obtain the address of Jose C. Rendon, and would thank any alumnus for information that would enable us to communicate with him.

'86.

CHARLES RUSSELL COLLINS was married to Anna Irwin Chapin, daughter of Mr. William Castner Chapin, on Tuesday November 10, 1891, at St. Luke's Church, San Francisco, Cal. Mr. and Mrs. Collins reside at 727 Brown Street, Philadelphia, Pa.

E. J. COOK, Constructing Engineer, and EDWARD F. WHITE, Vice-President, Field Engineering Company, Central Building, New York City, have been elected members of the American Society of Mechanical Engineers.

WILLIAM E. SCHOENBORN, Assistant Examiner in U. S. Patent Office, Washington, D. C., was elected to Junior Membership in the American Society of Mechanical Engineers, in November, 1891.

W. F. WHITE is a manufacturer and importer of machinery in Mexico City, Mexico, being the successor in business to his father, the late John White.

'87.

ROBERT M. ANDERSON has been appointed Instructor of Applied Mathematics at the Institute.

ALFRED H. SCHLESINGER is the Mechanical Engineer and Assistant to Manager of the India Rubber Comb Company's Works, at College Point, N. Y.

S. W. MILLER is located at Columbus, Ohio, with the Pittsburg, Cinn., Chicago & St. L. Ry. Company.

'88.

EDWARD DUCOMMUN has been with the H. R. Worthington Hydraulic Works, Brooklyn, N. Y., since July last.

'90.

HARRY P. JONES and L. D. WILDMAN have been elected Junior Members of the American Society of Mechanical Engineers.

EUGENE E. HINKLE is the engineer of the Union Iron Works, office in Columbia Building, 29 Broadway, New York City.

FRANK MOYNAN is in the employ of the Illinois Steel Company, South Chicago, Ill.

G. L. TODD is Assistant in the Department of Tests of the C. B. & Q. R. R., and is located at Aurora, Ill. Mail will reach him if sent care of G. W. Rhodes, Supt. Motive Power, C., B. & Q. R. R., Aurora, Ill.

FRANCIS B. STEVENS, JR., is with H. R. Worthington, Hydraulic Works, Brooklyn, N. Y.

'91.

F. B. DEGRESS is with the Crocker-Wheeler Motor Company, 430 West Fourteenth Street, New York City.

J. ALFRED DIXON is Assistant Engineer of the Safety Car Heating and Lighting Company, 160 Broadway, New York City.

JOHAN M. HANSEN is in the employ of the U. Gas Imp. Company, Drexel Building, Philadelphia, Pa., in the capacity of cadet engineer.

ALFRED P. BOLLER is with H. R. Worthington, Hydraulic Works, Brooklyn, N. Y.

H. W. SMITH is draughtsman for the Samuel S. Moore & Sons Company, Elizabeth, N. J.

PAUL SPENCER is with the Field Engineering Company, Central Building, New York City.

F. L. JOUBERT is connected with the Louisiana Sugar Exp. Station, 75 Carondelet Street, New Orleans, La.

LOUIS B. WALKER is draughting for the Baltimore Electric Refining Company, Keyser Building, Baltimore Md.

C. E. PEARCE is with the J. M. Ives Company, Danbury, Conn., acquiring valuable experience by his association with Mr. Burchard, '85, who is the Mechanical Engineer of this company, besides being the engineer for the Electric Light Company, which is building a new modern electric station, to be equipped with three 100 H. P. Otto gas engines.

The Ives Company are also agents for the Hill Automatic Sprinkler Head, and have recently equipped the factories of the J. B. Williams Company, Glastonbury, Conn., with a complete automatic fire protection system, in the erection of which Mr. Pearce was also engaged.

W. S. ACKERMAN and C. G. ATWATER were elected in November, 1891, Junior Members of the American Society of Mechanical Engineers.

JULIAN C. SMITH'S present address is 1401 Park Avenue, Baltimore, Md.

EDWIN S. LORSCH is draughtsman for the Geo. F. Blake Manufacturing Company, East Cambridge, Mass.

J. A. NORCROSS is chemist in the Consolidated Gas Company, Ninety-ninth Street and Second Avenue, New York City.

A. R. MOUNT is draughting for the Wallis Iron Works, 7–15 Morris Street, Jersey City, N. J.

BOOK NOTICES.

ACCESSIONS TO INSTITUTE LIBRARY, JULY 1 TO DECEMBER 31, 1891.

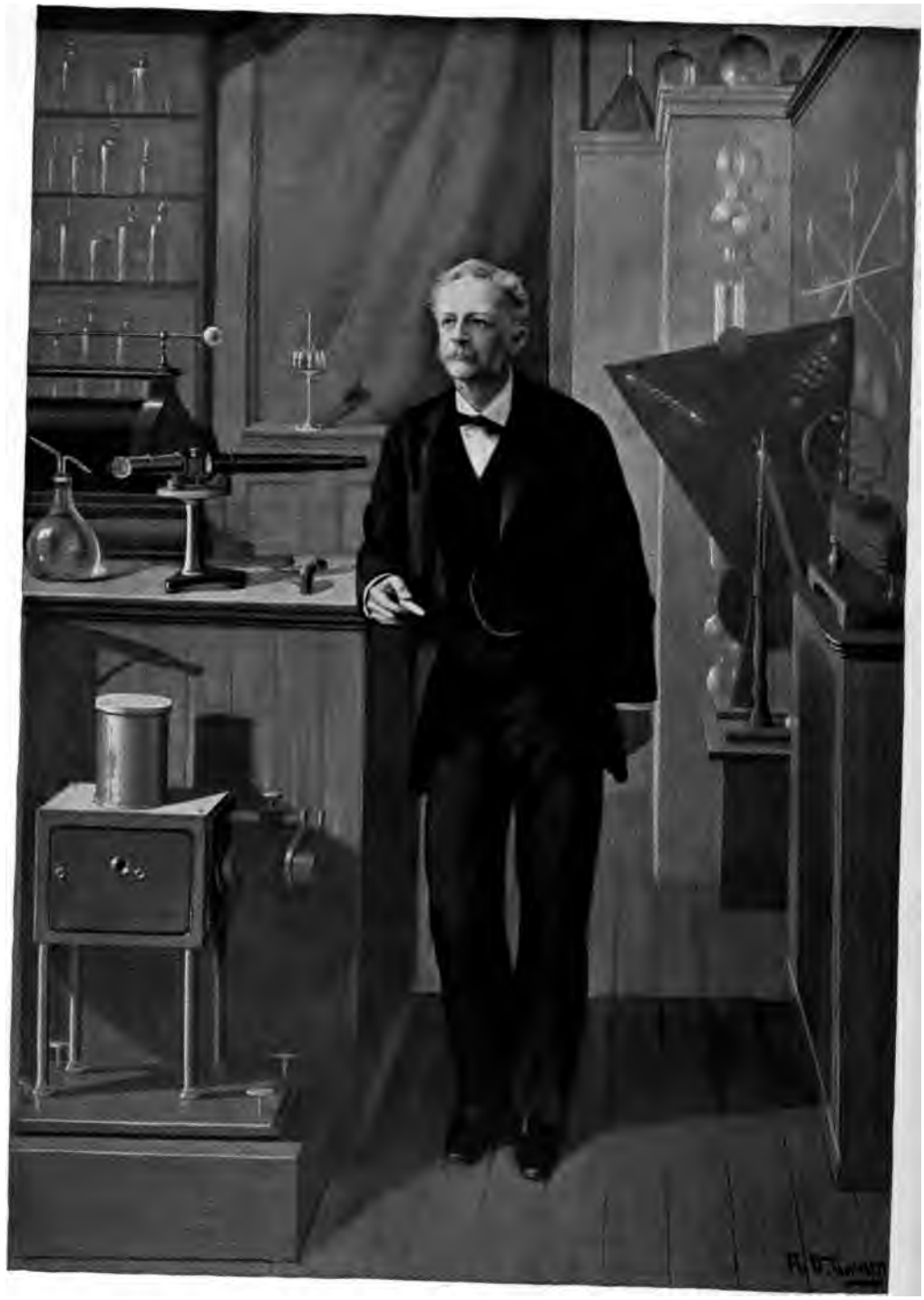
By Purchase:

Berichte der Deutschen Chemischen Gesellschaft, 1888, 89 *and* 90
Electrician (*London*). Vol. XXVI.
Engineer (*London*). Vol. LXXI.
Engineering (*London*). Vol. LI.
Journal Chemical Society. Vols. LIX. *and* LX
Scientific American. Vol. LXIV.
Scientific American Supplement. Vol. XXXI.
Nature. Vol. XLIII.
Jahresbericht, Wagner's. Vol. XXI.
Zeitschrift der Anal. Chemie, 1888, 89 *and* 90.

Electrical Engineer (*New York.*) Vol. XXXIX.
Comptes Rendus. Vols. CX. and CXI.
Electrical World. Vol. XVII.
Boiler Tests. By Geo. H. Barrus, Boston, Mass.
The Century Dictionary. Vol. VI.
Handbook of Industrial Chemistry. By S. P. Sadtler.
Specifications and Drawings of Patents. Parts 1 and 2, May, June and July, 1890.

Contributed:

By Prof. Denton: *Vergleichende Versuche an Kältemaschinen.* Data of the First Series of Experiments on Refrigerating Machines at the Experimental Laboratories at Munich.
By Brown & Sharpe Manufacturing Company: *Construction and Use of Grinding Machines.*
By Alfred C. Selwyn: *Report on Rivers of Johnstown, Pa.*
By J. James R. Cross: *Geological Survey of Canada,* 1888 *and* 89.
By J. Wiley & Sons: *Manual of the Steam Engine.* By R. H. Thurston.
By E. P. Thompson: *How to Make Inventions.* New York: D. Van Nostrand Company.
By Stevens Indicator: *How to Become an Engineer.* By Geo. W. Plympton. New York: D. Van Nostrand Company. (Sci. Series.)
By Dr. Stillman: *Zeitschrift fur Angewandte Chemie.* Berlin: J. Springer. *French, English and German, Eng., Germ. and Fr., Germ., Eng. and Fr.* Dictionary.
By Royal Society of Canada: *Proceedings and Transactions.* 1891.
By London Inst. of Civil Engineers: *Minutes and Proceedings,* Vols. CV., CVI. and CVII., and *Charter, By-Laws and List of Members.*
By Bell Street Chapel: *Thoughts on Religion and Morality.*
By New York R. R. Commissioners: *Report on Bridge Strains.* 1891. Albany: Weed, Parsons & Co.
By Department of Labor: *Reports of the Commissioners of Labor on Railroad Labor, Iron and Steel Productions, Marriage and Divorce.* Washington: Government Printing Office.
By U. S. Coast and Geodetic Survey: *U. S. Coast and Geodetic Survey Report.*
By Navy Department: *Washington Observations.* 1891.
By Smithsonian Institution: *Experiments in Aerodynamics.* By S. P. Langley. *North American Fresh Water Fishes. The Anatomy of Astrangia Danal.*
By U. S. Navy Department: *American Ephemeris and Nautical Almanac.*
By Institute of Mining Engineers: *Transactions.* 1891.
By A. B. Farquhar: *Economic and Industrial Delusions.* New York: C. P. Putnam's Sons.
By U. S. Patent Office: *Official Pat. Gazette.* Vols. LII. and LIII.



PRESIDENT MORTON.

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THE STEVENS INDICATOR.

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ADDRESS OF PROF. COLEMAN SELLERS, E. D.,

IN RECEIVING PORTRAIT OF PRESIDENT MORTON IN BEHALF OF THE FACULTY.

THOUGH the youngest member of the Faculty, in reference to the date of my appointment, my selection to receive this portrait of President Morton as their representative has this appropriateness, that I am by far his oldest friend, having known him both in his professional and domestic life for more years than I like to mention; our intimacy dating far back of the foundation of this Institute, with his coming to my house to see a little piece of magneto-electric apparatus which I had constructed to illustrate one of the curious interactions between a magnet and a galvanic current discovered by Faraday; and from that time to this, with only such interruptions as geographical distances have interposed, our relations have been of the closest character.

When I first knew him he was just beginning his scientific work, making much of his apparatus with his own hands, and similarly preparing the large colored diagrams which he often required for the illustration of his class lectures. In this work he found a willing and able assistant in his wife, and I can well remember visiting his study when both were engaged on the same large drawing with brush and pencil, covering huge surfaces of canvas-backed paper with such illustrations.

I have no doubt that all of you have seen some of these diagrams, and have profited by them as means of explaining difficult problems in optics and other subjects.

I have another example of the artistic work of these, my dear friends, in an illuminated manuscript volume which I preserve among my choicest treasures.

Even prior to this period, and while yet an undergraduate in the University of Pennsylvania, and during the year immediately succeeding his graduation, Mr. Morton had achieved a reputation by no means limited to this country, through his work in connection with the translation of the Greek, Demotic and Hieroglyphic inscriptions on the Rosetta Stone, which was the substance of a report to the Philomathean Society, the principal literary society of the University.

This report was published as a square octavo of 172 pages, more than 100 of which were decorated with original designs in color executed on stone by Mr. Morton, who also made the translation of the hieroglyphic text.*

The opinion entertained as to this work by the highest authorities may be gathered from the following extract of a letter, written by the famous Baron Alexander Von Humboldt, to one of the committee who had the matter in charge.

"The scientific analysis of the celebrated incription of Rosetta, which, despite the confusion of the hieroglyphic style, remains an historical monument of great importance, has appeared to me especially worthy of praise, since it offers the first essay at independent investigation offered by the literature of the New Continent. It is for this national relation that I specially greet this independent work.

"Little versed myself in this class of studies, I ought, however, to greet the so conscientious work of the learned committee of the

*As this work is now very rare the editors are much pleased to be able to insert here a reduced copy in black and white of one of its illuminated pages. This plate is reduced about 2¼ inches in height and 1¼ inches in width from the original.

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That the hieroglyphic signs consist of, 1st. Phonetics or letters. 2nd. Ideographs, or signs of ideas, as a figure of a man for the idea 'man', of a lotus for 'lotus', &c, 3rd. Determinatives, or signs affixed to ambiguous words, to denote to what class of objects the thing signified belongs: As if we, having the word 'pike', either for a fish or a weapon, should draw a conventional form indicating fish, after the word when used in one sense, and a sign for weapon in the other.
That the language thus expressed, was intimately allied with the Coptic: differing mainly by reason of a greater simplicity of grammatical structure and of primary roots,

REDUCTION FROM PAGE 66 OF THE ROSETTA STONE REPORT.

Philomathean Society, since the results now obtained contribute to prove the justice of the system of Champollion, to which my brother, William Von Humboldt, was the first to render justice in Germany.

"The picturesque ornaments added by Mr. Henry Morton add to the interest inspired by a work well worthy to be widely spread in your learned and free country."

Such an endorsement was no small triumph for a young man just passing from the shelter of his Alma Mater.

Not many years after my first aquaintance with Mr. Morton, I was instrumental in affording him an opportunity for the development of his special capacities, by bringing about his election to the office of Resident Secretary of the Franklin Institute in Philadelphia.

This time-honored institution experienced in 1865 a radical revival and development to adapt it to the times, by reason of the active interest taken in it by the principal mechanical engineers and manufacturers, and Mr. Morton was selected to be the executive officer, by whom the desired new development was to be carried into effect.

At one of the first meetings of the Managers of the Institute after Mr. Morton's appointment, it was suggested that an excellent means of interesting the public at large in the objects of the Institute would be a course of scientific lectures, delivered in some large hall.

One of the managers was even so bold as to suggest the Opera House or Academy of Music, one of the largest auditoriums in the country, seating over 3,500 persons. Others considered this too venturesome, but it was finally decided to leave this to Mr. Morton's decision.

Deputed to communicate with Mr. Morton on this subject, I well remember the characteristic courage and enthusiasm with which he at once seized ont he idea of making the so-far unparalleled experiment of devising and executing illustrations on such a scale

as should render them impressive on so large a stage, and to so vast an audience.

All who came in contact with him were inspired with his confidence and enthusiasm (myself among the number) and the preparations were commenced at once.

Some notices of these got abroad, and long before the date assigned for the lecture, every seat in the house was sold, and so pressing was the demand, that the Acadamy was engaged for another evening, a few days later, and, before the night of the first delivery arrived, every seat had been again sold for the repetition.

There are occasions, even in the life of a scientific professor, which call for no small stock of moral courage, and the evening in which Mr. Morton for the first time walked forward upon a public stage in the face of an audience which crowded every seat and every inch of standing room, with the consciousness that he was committed to the absolute necessity of a success by the arrangements for the repetition, was one of them.

I was with him at the time, having undertaken the office of manager to direct and superintend the work of his assistants behind the screen; and I have not forgotten what were my own feelings.

But when the curtain rose, he stepped forward with easy grace, amid the enthusiastic applause which greeted his appearance, and began his lecture as calmly and collectedly as if he had done the same thing fifty times before.

He told me afterwards that he was so anxious about the success of his experiments, that he had no room in his mind for personal embarrassment, or the nervous agitation often caused by facing a great audience.

I need hardly say that the lecture was throughout a success.

The clearness of the explanations, and the novelty and beauty of the experiments, held the audience in close attention for nearly two hours, and when Mr. Morton made his exit from the stage, amid applause even heartier than that which had welcomed him, he car-

EXPERIMENT WITH MONOCHROMATIC LIGHT AT THE ACADEMY OF MUSIC.

ried with him a reputation as a scientific lecturer which, I believe, has never been equaled.

During the following years similar lectures on related subjects were given by Mr. Morton in the same place.

Some of their titles were the following: "Reflection," "Refraction," "Sunlight," "Moonlight," "Eclipses," "Fluorescence," and so on.

In these lectures Mr. Morton used not only numberless new devices for the production of striking illustrations of scientific phenomena, but also brought into play the appliances of the stage, such as shifting scenery to aid in color effects, stage traps to bring apparatus into position when wanted, and endless other applications.*

In looking over some old papers a few days since I came across some interesting relics, pertaining to these lectures in the shape of notes in Mr. Morton's writing, which were for my use as "stage directions" in the management of his assistants and in securing the prompt and orderly succession of the experiments.

They form curious reading and well illustrate how complex were the combinations and how necessary was complete organizations and co-ordinate action, to the successful presentation of these experiments.

One of these memoranda read as follows:

"Then when through McIntyre will show Dia. 6, Mr. Brown, Mr. Higby, etc., will then remove truck and lantern, while Mr. Sellers removes electric lamp to table and makes connections ready. Then Mr. Higby will *run in the angel*, Mr. Sellers will light up electric lamp, Mr. Brown will light a red fire, and Mr. Stewart a piece of magnesium as also Klapp, Phillips, etc.

*NOTE.—Through the kindness of the Committee, who are preparing a biographical souvenir of the last meeting, we are able to introduce a picture showing the interior of the Academy of Music during one of the experiments in which the stage was illuminated with yellow light from the monochromatic burners devised by President Morton, so reducing to *black and white* the brilliantly colored decorations of the scenery and the dresses and banners of the masked figures, representing the colors of the spectrum and other tints, who had previously marched in under a blaze of white light which brought out every tint with vivid effect.

"Then Mr. Higby will *run out the angel* and McIntyre will show Dia. 7 and 8, while Mr. Sellers removes the electric lamp and gets ready red and green fires.

"Show shadow of veil and needle. Send out lantern by Klapp and Phillip.

"Higby will then *run in earth and work moon*, then run off these and bring in movable flat.

"Mr. Higby will then *run in mountains* on background and bank in front while Mr. S. *sets the sun on floor in position for rising*. Show Spectre of Brocken. During this time Mr. S. will arrange the other electric lamp behind the mountains for next experiment.

"The Outerbridge will tell Mr. Higby to lower white curtain, raise horizon, drop and *run out mountains*, and McIntyre to show diagrams 3 and 4.

"Experiments with electric light in the sun. Mr. S. on signal from Outerbridge will light up and have Combat of giant and dwarf. Klapp and Outerbridge. Rabbit on chair. Carry off men in hand, run about and step into ceiling, etc., etc., etc."

I also find among my notes the perorations or concluding paragraphs of two of Mr. Morton's lectures, which are interesting as illustrating the poetical forms of expression which, judiciously introduced, added not a little to the charm of these discourses. The first was the conclusion to the lecture on "Light," in which the analogies, or rather close relations, between sound and light, had been dwelt upon and fully developed.

It reads as follows:

"From what has been seen this evening I hope that you will be able to attach a more definite meaning to that frequently used, though vague expression, 'the Music of the Spheres.'

"There is such music. All day long from the glowing sun pours down an harmonious flood of commingled 'light' notes, which are echoed, reflected and reverberated in a thousand accordant tones, from various natural objects. Then, when night comes upon the earth, the stars and planets from their far-off seats above the clouds,

send down songs, fainter but not less sweet; like the voices of birds, singing as they float and circle amid the sky. And always and in all places, amid the nearer planets, and amid the more distant stars, and throughout the vast abyss of the Universe, floats everywhere, floats eternally, that commingled symphony of luminous vibrations, which constitutes the grand visible anthem of Nature, the true 'Music of the Spheres.'"

The other passage was the conclusion of a lecture on color, in which the composition of sunlight and the characteristics of light from colored stars had been among other things fully explained. It runs as follows:

"As a merely poetical, and not very strict analogy, we may regard this experiment as a spinning of colored light threads into a single white cord. From the lantern to the screen, run at first the seven colored threads, distinct and distinguishable at every point—then we give motion to the painted glass, and twist these seven bands into a single compound fillet of white light.

"Carrying out this idea into our contemplation of the astronomical universe it naturally develops itself into a very beautiful thought.

"We seem to see the countless stars, each throwing out a web of light rays; some, like our sun, of woven white, others of every rainbow dye. Through this vast variegated web flash constantly the golden shuttles of the comets, weaving together into compact perfection, the great and glorious universe, the 'garment of God.'"

During the years from 1865 to 1870, both included, Mr. Morton was the executive head of the Franklin Institute, and editor of its journal, to which he contributed numerous articles. He also during the later years of this period filled the chair of Chemistry at the University of Pennsylvania.

He also in August of 1869 organized and conducted an expedition to make photographs of the total solar eclipse, which was visible on the 7th of August of that year in parts of Iowa.

Professor Morton's party took two large equatorial telescopes with them, and were remarkably successful; the result of their work will be found in numerous scientific journals and books on astronomy published all over the world, as well as in a special volume published by the U. S. Government as part of the Nautical Almanac records.

In this connection Mr. Morton made a remarkable discovery concerning the cause of a bright line on eclipse photographs, which had baffled the explanation of some of the ablest astronomers.

Mr. Morton's communication on this subject was presented to the French Academy, and published in their Transactions, the "Comptes Rendus."

In the summer of 1870, however, Mr. Morton's scene of activity was removed from my immediate vicinity, and he came on to Hoboken, to organize and labor for this institution.

Since then, though our affectionate intercourse has been as close as circumstances would admit, I must abandon all claim to special knowledge, and rather learn from you than tell to you, how he has labored and what he has accomplished.

Gentlemen of the Alumni Association of the Stevens Institute of Technology, in the name of the Faculty, I accept this gift and tender to you hearty thanks from ourselves and from all President Morton's friends, who recognize in this picture a fitting illustration of one page in his active and useful life.

COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

V.—LECTURE NOTES—"OBSERVATIONS MADE IN EUROPE BEARING ON QUESTIONS OF WATER-WHEELS."

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MY detention in England during many months and during the time when I should have delivered my course of lectures in the Stevens Institute for the year 1890, was on business connected with the development of the water-power of Niagara. It has given me a chance to study engineering practice in England, and also in France, Germany, Switzerland, and even in Italy.

The proposed utilization of a small percentage of the power going to waste at Niagara Falls will require many million dollars to be invested before any return will come to those who believe in the practicability of the scheme.

A tunnel tail-race from land on the American side of the river above the upper rapids under the village of Niagara Falls to discharge the water that will pass the wheels into the lower river is now being constructed. The wheels are to be located in pits. Of the 215 odd feet difference of level between the upper and the lower river, in the neighborhood of 140 feet will be taken as head to drive the wheels, the difference between the head taken for power and the total head being used to enable a tunnel of about 20 feet 4 inches diameter to carry off the water that will, at say 140 feet head, yield 100,000 horse-power. This 100,000 horse-power is less than 4 per cent. of what Niagara has to give to man's use, but is an amount of power greater than all the power in many of the largest manufacturing centres combined. The area of land required

to use so much power can be obtained only by transmitting the power to a great distance from the Falls. There is room for only a limited number of mills or factories close to the end of the tunnel, and the total area that could be developed by surface canals and extension of the tail-race tunnel is not great enough to absorb the whole amount.

By creating the power wholesale in a central station, it may be delivered to factories over an area contained in a radius of 20 miles, and this distance will bring the great and rapidly-growing city of Buffalo within reach of the power so generated.

As precedents to guide us in this work, many great streams have been improved and the water-power so created distributed over cities near by. As, for instance, at Geneva, Switzerland, where the work of the improvement of the Rhone has done away with many private mill enterprises fed direct from the stream, and extended the power over the city in a most advantageous manner.

The vastness of the Niagara enterprise calls for a thorough knowledge of what has been done and what can be done, the study requiring much time.

During May, 1890, I was called to London by a cable from Mr. Edward D. Adams, the President of the Cataract Construction Company, to discuss with him the subject of a centralized creation of power and the transmission of the power to Buffalo and elsewhere—to places where manufacturing enterprise is now calling for cheap and efficient power.

Together we visited Paris, where electricity and compressed air are used for power; Geneva, where water under pressure is distributed for power; and the great workshops where turbines, pumps, compressors and electrical machinery are made. This conference with leading engineers indicated the sources from whence valuable information might be obtained.

It was finally proposed to place the collected information in the hands of an International Commission, which would consider plans that might be submitted to it, and might award prizes to those ıes that seemed worthy of such honor.

A large number of engineers and engineering firms were requested to submit plans, and the Commission was organized under the presidency of Sir William Thomson, now President of the Royal Society, and known to all men as one of the greatest electricians living. Professor Mascart, of the Institute of France and Director of the Meteorological Bureau of Paris, was named to represent France. Col. Th. Turrettini, Mayor of Geneva, who is director of the works for the improvement of the Rhone at Geneva and noted for his connection with the St. Gothard Tunnel, was selected for Switzerland, while I was appointed to represent the United States and the interests of the American company. Prof. W. C. Unwin, Dean of the Faculty of the Guilds School, and Professor of Mechanics in that institution in London, so well known as a hydraulic engineer and a writer of engineering text-books, was induced to give up his summer vacation to act as Secretary of the Commission.

About twenty engineers, or firms or combinations of engineers, were selected to submit plans; first, for the primary creation of power; second, for the transmission of power and its distribution to meet all the requirements of a manufacturing district, or to submit combined plans for creation and distribution of power by what each considered the best method.

The plans and estimates were to be sent in on the last day of December, 1890, the Commission to meet January 29, 1891.

It was expected that each would give the matter unusual attention, not only on account of the prizes, but because each one who should comply with all the terms of the invitation would be paid many hundred dollars for the work.

The European competitors for the prizes offered by the Cataract Construction Company sent in, in some cases, most voluminous reports, with numerous drawings, executed in superior manner and accompanied by volumes of descriptive text.

This great collection of information from leading men did what was expected; it brought suddenly into shape the expressed

state of the art in water motors and means of transmitting power up to the present time in a manner far more thorough than could be expected to be collected in the ordinary course in many years.

I bring this subject to your attention, as it enables me to show you the advantage of scientific engineering as compared with much that is of an empirical character.

Regarding water wheels or rather turbines, as in Europe turbines are not always spoken of as water wheels, that name pertaining to the old form of overshot, breast or other water wheel in use before the Jonval turbine was invented, a useful lesson is to be learned from the method of treating this subject at home and abroad.

In America many turbines are made that yield a high efficiency mostly at full gate, and these wheels have, as a rule, some patented feature and are called by trade names peculiar to the makers. These wheels are well adapted to moderate heads, the Pelton wheel giving excellent results at unusually high heads. Turbines increase in speed of rotation with each additional foot of fall, and the tabulated list of wheels, and what they will do enables manufacturers to select the one suited to their requirements within reasonable limits of power and speed.

Few of the patent wheels in use here are adapted to heads greater than 100 feet, and at that head their speed of rotation is unmanageable in most cases. It is difficult to adapt such trade wheels to what is wanted at Niagara where the head may be 140 feet, and where the speed must be slow or fast, according to the machinery that is to be driven, the units of power being anywhere from 2,500 horse-power to 10,000 in each wheel.

In Switzerland, in France, in Hungary and in England, wheels are not made in all cases in graded sizes and manufactured like stoves or car wheels. They are constructed on well known scientific principles to yield within reasonable limits the required speed and amount of power at the given head.

More than one noted engineer agrees that inasmuch as marine engines of 12,000 horse-power transmit the whole of that great

power through one shaft many hundred feet in length to the propeller, and such engines run night and day for long periods of time without trouble, so may a turbine of 10,000 horse-power transmit its power to the surface of the ground a distance of, say, 120 feet, there to drive a dynamo of 10,000 estimated horse-power, or to work compressors for air or pumps for water, or to distribute power by cables to the factories. Such proposed turbines have never as yet been made, as no industries have ever demanded such large blocks of power.

Some engineers holding to the ordinary practice, arrange a solid vertical shaft with numerous bearings to steady it, but others recommend a hollow shaft, and as it is vertical and not liable to any deflection, argue that one bearing at the wheel and one at the top of the pit is all that will be required. They give many forms of wheels that may be classed as reaction or pressure wheels of the Jonval type or impulse wheels of the Gerrard type, or modifications of both or either. The drawings submitted show many novel degrees in wheels and much that is new in modes of governing speed.

Some fill up the air space in the wheel by curved plates that enable the reaction wheel to be served with a draft tube and raised some 20 feet above the tail-race, and by proper modification give the required speed, slow or fast, with the stated head, just as the Pelton wheel of San Francisco can be arranged to give any speed with unusually high head. Some impulse wheels are thus improved with a view to run passably well in back water, others requiring to be kept high enough to be above all possible use in the tail-race.

When we come to the transmission of power we find that by far the greatest number submit plans purely theoretical of transmission by electricity, or plans varying greatly in all particulars, but grounded on actual practice of transmitting by compressed air, few advocating transmission by wire rope.

This wire rope transmission, once the pride of Swiss engineers, is now giving way to electricity, and the transmission of the future

will be disputed between electricity and compressed air. The maximum transmission by wire rope is about 1,000 horse-power, by three wire ropes acting separately, each handling about 333 horse-power.

The engineers of the Birmingham compressed air system advocate air mains 20 miles long of 10 feet diameter. The engineers of the more extensive compressed air system in Paris, say two air mains of 26 inches are large enough to send to Buffalo 50,000 horse-power, but on occasion one can be made to do the work at a greater pressure. American engineers give the tabulated value of mains up to 48 inches diameter as the largest. Pressure varies from 70 pounds, above atmosphere, up to nearly 200 pounds per square inch, and the system of compressors vary with each engineer.

One engineer advocates single-acting compressors and outside cooling only, saying that at moderate pressure the heated air can be used to advantage while still hot near to the compression station, the large mains acting as reservoirs of power and equalizers of the work.

Others cool by injection into the cylinder, and claim that the temperature need never rise over 10 degrees. Again, it is urged that by double compression and cooling between the two sets of compressors the best results are obtained, as unless the cooling is all done before the discharging valves open, any later cooling is of no use, as the work has then already been lost.

Whether or not in the rapid movement of the piston in the compressor the heat set free by compression can or cannot be taken up before the ejection valves open—*i. e.*, before the working pressure has been reached and the air has begun to flow out of the cylinder and into the air mains, has not yet been decided. The question is very much the same as was raised with the low pressure steam engines years ago, when the short time allowed for condensation of the steam was against it, but we do know that the steam is suddenly condensed, and a fair vacuum is possible with the maximum speed of piston motion.

We know that much of the power of the air is lost by compression in loss of heat, that condensed air will not by reason of loss of heat re-expand to its original volume; but for all that, the process is not so wasteful as some imagine.

The cooling effect of the expanding air can be made to return a money value in reducing the temperature of storage chambers for keeping meats, etc., thus taking the place of more costly ice. The compressed air can be heated before entering the engine, with great profit and little fuel, as each degree of heat given to the compressed air tells at once on its expansive value, there being no latent heat to be expended before expansion begins, as with the conversion of water into steam.

There is at present a decidedly active controversy between electricians and those who advocate the transmission of power by compressed air, but the air compressors are yielding good results, and the system is about being extended over many of the leading European cities of the first class.

The problem of transmission of power by compressed air is so interesting that I hope to make my study of the subject the matter for a separate lecture.

It has been my wish to share with you some of the great amount of information that I collected while on this interesting work in Europe. I have brought with me to-day the drawings submitted by one of the firms who received a prize awarded by the Commission, and these represent the plans submitted by the firm of Escher Wyss & Co., of Zurich.

The work of this firm is well known throughout Switzerland, and I was particularly impressed with the plant erected by them at Geneva, where the improvement of the Rhone was carried out under the administration of Colonel Turrettini, who is now, I am happy to say, the foreign consulting engineer of the Cataract Construction Company.

This particular installation at Geneva is shown and described in quite an elaborate work issued by Colonel Turrettini, in which

publication he gives not only the accepted plan but the plans that have been rejected after due consideration.

In regard to the pumps used at Geneva, I wish to call your attention to an interesting fact; that is, the plungers of the pump are not made square at their ends, but are formed like the end of a minie rifle bullet, pointed; and I am assured that by means of this pointed-ended plunger they have been enabled to very much increase the running speed of the pumps over what had formerly been possible with the square-ended plunger.

I wish to call your attention to the proposition made by Escher Wyss & Co., from the fact that they offer turbines which are of well known types, and yet so formed and proportioned as to be able to give a slower rotation in proportion to the head than many of the various types of wheels that have been submitted. The speed of rotation that they have named is in fact lower than probably will be required for much of the work at Niagara, but at the time that they began this work it was confidently expected that they would have been able to have co-operated with the celebrated Maschinenfabrik, at Oerlikon, under the advice of Mr. Brown, the celebrated electrician of that firm, but sickness on the part of Mr. Brown, or military service, or some other reason which I have now forgotten, prevented them entirely from carrying out their part of the programme, and at the last moment, Escher Wyss & Co. were obliged to send in their proposition for the primary creation of power without the accompanying paper, which would have raised them into that class of competitors who entered for a combined project of creation of power and transmission to a distance.

Referring to the document that accompanied their drawing, I shall quote that they offer 12 double reaction turbines with horizontal shafts, each calculated for a net fall of 137 feet 9 inches, or 42 meters, and a quantity of water of 850 cubic feet per second, realizing each 10,000 effective horse-power at a normal speed of 240 revolutions per minute. They offer again four reaction turbines with horizontal shafts, each calculated for the same net fall, and

for 1,000 litres per second of water, realizing each 400 effective horse-power at a normal speed of 480 revolutions per minute. Then again, they offer two reaction turbines with horizontal shafts, each calculated for net fall of 124 feet 8 inches, or 38 meters, 300 litres, per second, realizing each 100 effective horse-power at a normal speed of 480 revolutions per minute.

They say that the existing local conditions prescribe the use of motors which can be easily erected in pits designed for receiving them, and which are not to occupy much room, and for this reason they consider the reaction turbine as the one which, undoubtedly, before all others, offers the greatest advantages because, as they show in their project, it is constructed for larger power and high speed, and at the same time requires comparatively small space.

They cite various methods of transmitting power, such as by shafting, by wire rope, by water pressure, by compressed air, and in recent times, by electricity. They think their turbine is well adapted for the use of those factories that can be built immediately over the tunnel, or near enough to it to be operated each by its own water-wheel, though they say they have furnished no drawings, being short of time, and because the problem is simple and requires no special description. They claim that their turbine, with complete counter-pressure for the movable parts, is especially adapted for this purpose.

In regard to wire ropes, used formerly only because there was no better method known, they are not to be recommended for application on so large a scale as the present one, and to quote their own words, "experience has shown that the use of wire rope is most uneconomical, absorbs too much power, and is subjected to frequent interruptions. The net force delivered by such transmission where power is to be conducted to some distance would be comparatively small. Further, the chief inconvenience, the distribution of power, offers great difficulty. A large number of cables would have to be employed, and to be drawn across elevated buildings; interruptions of work by rupture, yielding and slipping of ropes, increase with the

number of stations." The noise also from these ropes, they say, is very disagreable, and this I fully confirm by my own observation. They consider it impracticable to draw a system with such cables across an industrial town. Experience at Schaffhausen, Bellegarde, Fribourg and Zurich shows this sufficiently. This system of transmission may, in some special cases, seem to be justified, but with many others, and with all electricians, they believe that for an installation like this one, requiring the transmission of power from a large central station in many directions, it would not serve as a chief transmitting agent.

Water under artificial pressure, they think, would promise better results if it were likely that only small power was to be supplied at short distance. This, however, is not the case at Niagara; besides, this system presents some other inconveniences, such as inundations through bursting of pipes, frost, etc., but mainly because the situation of Niagara offers no elevated ground, say from 250 to 300 feet above the level of the pumps, to receive reservoirs for the storage of water. They therefore consider that compressed air and electricity are the only modes of transmission upon which to base this project.

It may be interesting to you to know that they, as engineers of very considerable experience, consider compressed air to be inestimably preferable to water, permitting larger motors and compressors to be combined with smaller dimensions of pipes, by which arrangement power may be transmitted even to greater distances with less cost than by water pressure.

There also exist certain industries for which air only can be employed, and in their study of this subject they made it serve as a comparison with the electric system. Like many other engineers, they are inclined to consider as the most convenient solution of the utilization of Niagara power, the application of electrical energy, even if only on account of allowing successive extension, as they say electricity alone delivers large or small power to any given distance, and offers, possibly, the greatest facility for further enlarge-

ment. In their project they supposed that all the power obtained will be transformed into electrical energy at the central station and applied as such to trade, be it for illumination, working of pumps, compressors, or various other industrial purposes, and they say that the great advantage of this system is that it promises, corresponding to the size of the motors employed, the use of large primary dynamos, which means simplicity and cheapness of plant. They, therefore, naturally directed their study chiefly to the arrangement of the motors, adapting them to the system of transmission chosen.

Plan No. 2 A of their drawings represented a plant of 100 groups of air compressors, every two of which groups are driven by one turbine of 2,500 horse-power, by means of spur wheels. This quantity of power could not be very well exceeded, as the compressors, and especially the wheels, are based on the highest speed allowed in practice. Then, on plan 4 B they submit a plant of 25 turbines of 5,000 horse-power each, with vertical shafts and directly linked dynamos. Plans 6 and 7 C would be a plant of 12 turbines of 10,000 horse-power each, with horizontal shafts, and each linked directly to two primary dynamos. The two last plans differ chiefly in this: That plan B shows the dynamos placed above ground driven by means of vertical shafts, while C shows them in turbine pits, directly coupled to the turbine shafts. The disposition of motors in A and B may likewise serve for direct coupling by wheels and shafts without having resource to electricity or pressure of air in the establishment, which could be built close to the pits.

All their turbines are constructed on the reaction system with partial sucking effect—*i. e.*, with draft tube, and with hydraulic counter-pressure gears, by means of which the step pressure is almost entirely done away with so that the step bearings are not likely at any time to become hot.

In one plan they provide a counter-pressure plate on the turbine shafts, moving in the upper part of the turbine mantle, and so proportioned as to counterbalance the pressure upon the step almost entirely. As the space above the counter-pressure plate is

in communication with the suction pipe, the counter pressure can be easily governed as required by means of a throttle hollow; and just here I want to call your attention to the fact that I noticed in all the turbines that I saw running in Switzerland that the plan was generally followed of making the turbine shaft hollow, and carrying the step above the turbine up through this hollow shaft by means of a vertical pillar, which is stationary, in the form of a section of turned shafting standing on its end, and resting on a cast-iron base firmly secured to the stone foundation below the wheels. Upon the top of this vertical shaft is a self-adjusting oil step bearing, which takes some of the weight that is not already counterbalanced by the pressure plates in the turbine.

They say that as the dimensions of the spur wheels require that the speed of the turbine be limited to 250 revolutions per minute, they have fixed the minimum diameter and adopted single turbines with counter-pressure plates, claiming that they have employed this system in several turbines in Switzerland, and many years ago in the cotton mill at Felsenau, at Berne, and more recently with four turbines, each of 400 to 600 horse-power for the aluminum works at Neuhausen, on the Rheinfeld. They suggest for turbines of 5,000 horse-power, where circumstances allow the use, double turbines, and by increasing the number of revolutions they can reduce the size, and consequently the weight of the transmission shafts. The average diameter of the two wheels corresponds with the number of revolutions, and those remain unchanged. The upper turbine, however, in corresponding with the resulting pressure is constructed with a larger crown than the lower one and forms towards the shaft a massive disk, so that the turbine wheel serves at the same time as a counter-pressure plate, and for this construction they have applied for a patent.

In plan C, there are two turbines of 5,000 horse-power each, placed one parallel to the other and erected in the most practical and simple way on one common shaft, though, to use their own words, " in this case whatever suction to one side or the other would

make a slight variation," and to meet this they have ring or collar bearings so as not to permit any collision of the wheels.

It may be interesting for you to have me now give verbatim a little extract from their paper in which they say as follows:

"Experience having sufficiently proved that partial admission as by regulating gear in the distributing wheel of reaction turbines, constructed for sucking effect, is absolutely impracticable, we have done without it, adopting the following original and new method. The speed regulator acts upon the distributing wheel by a small double hydraulic motor, which is moved forwards and backwards accordingly as the regulator goes up or down. The hydraulic motor works upon an inlet valve placed at the lower end of the suction pipe or on the 400 and 100 horse-power turbine, upon a throttle valve in the inlet pipe. Both inlet pipe and throttle valve can also be moved by hand. Further, we have provided an automatic apparatus, which will act as soon as the inlet valve or throttle valve stands quite open.

"In order to be sure that a vacuum is formed in the suction pipe, the outlet of this is shaped like a plate." [A metal pan suspended below the suction tube into which the tube dips, and this pan is made adjustable to regulate the discharge.—C. S.] "A partial working of the turbine is therefore obtained in this case by means of a throttle valve, which, even if the net effect be somewhat diminished, will be of no disadvantage, considering that a profitable net effect has importance only when the turbine works at full power. We hold it of much greater importance to find out a simple regulation with easy attendance of the whole plant, and believe that we have completely solved this problem by the construction we propose."

In regard to the material from which these turbines will be made, after having carefully considered the use of bronze, they have decided upon cast iron, supposing the water to be pure; and also having provided for regulation by a new method, they do not think that there is much to be apprehended from the consequences

of the sucking effect. Cast-iron wheels used at Niagara at 90 feet head have given out by pitting, the holes in the metal indicating a boring action of sand somewhat like the holes found in rocks by whirling stones driven by rapid currents, as from glaciers in Switzerland, or in the streams of the White Mountains in this country.

The work of this firm is to be seen, not only over all parts of Europe, but also in a great many places out of Europe, mainly in India.

The proper methods of governing the speed of turbines have been well worked out by many of the engineers of Switzerland, and I would urge you to give careful consideration to the value of water power as a means of imparting uniform rotation in preference to anything that can be done by steam, when you have the water in sufficient quantity, unvarying head, and of sufficient purity.

Quite recently a paper has been published bearing on this sublect, showing the cost of horse-power by steam engines, and in this paper considerable stress has been laid upon the use offered by steam, with some disparaging remarks as to water. Among those industries that require quite uniform speed of rotation may be cited the operating of dynamos, and I may say to you that it is a common saying among electricians in England and on the Continent, that, give them water to drive their dynamos and they have no apprehension, while when obliged to depend on steam, they examine carefully into the conditions of the engine that is offered to them for doing the work.

There is a form of water wheel in common use in Europe that is now being erected at Tivoli to supply the motive power to the dynamos which are to give the alternating current that is to be carried to Rome by aerial wires. The Roman installation, erected by Ganz & Co., is one of the most perfect specimens of alternating current plants that is to be seen in Europe. It is controlled and managed by the gas company. This gas company, knowing well that, sooner or later, electricity would be called for, thought that it

would be wise for them to establish a plant basing its steam capacity upon what coke they might spare from the products of their gas works. This is the well arranged and perfect plant to which I allude.

Further extension in Rome was never contemplated, but it is proposed to go about fifteen miles to Tivoli, where water power is plenty, and thence to transmit by alternating current at 5,000 volts to Porta Pia, where it will be transformed down to 2,000 volts and carried into the city of Rome by underground concentric cables of the Seaman type. The water fall at Tivoli is an exceptionally high one, 400 or 500, or may be 700 feet. Quite an extensive aqueduct has been built along the side of the hill, collecting the water that had formerly been going to waste, and carrying it to a water tower of very considerable height, and thence by pipe into a building that is erected on the side of the hill—a building that can be entered from the roof or any of the various stories below by what we call in America a switchback road, zigzagging down the hill. The water, under a pressure of 50 meters, is fed to the water wheels with horizontal axes, coupled directly to the alternating dynamos. Six dynamos, each of 350 horse-power, will be run as required, separate machines being never coupled mechanically, but always coupled electrically in parallel.

It may be interesting to note that in Rome the experiment was tried for the first time of electrically coupling the alternating dynamos. In this Tivoli plant the water that has passed through the wheels that I have just mentioned, will be received into pipes, and there for the present allowed to go to waste, but is to be utilized in the future by another fall of 50 meters, to operate a still greater extension on the same line of the electrical plant.

ADDITION TO LECTURE ON TRANSMISSION OF MOTION.

BY PROF. COLEMAN SELLERS.

IN the equipment of any large establishment with line shafting, the distribution of power by this means will be effected in the first place by the main line, and from the main line thence to countershafts that will be placed near to each machine that is to be driven.

The term countershaft in the present case will be confined to one single shaft sufficient in length to accommodate the hangers, one on each end, fast and loose pulleys, of which in some cases there may be three when the motion is to be reversed by means of an open and a cross belt, but in the majority of instances two, one fast and one loose pulley, and the pulley that is to carry the motion to the machine, this pulley being either a single one or made as a cone with separate lifts to agree with the cone upon the machine that is to be driven, as in the case of lathes.

Now, for many years it has been customary to consider that the most economical method of designing such a shaft is to make the body of the shaft sufficiently large for the pulleys, that is to say, to secure rigidity and sufficient diameter to prevent the pulleys slipping upon the shaft, but, inasmuch as the loose pulleys require careful oiling, and as the countershafts need not have the journals so large as the shaft itself, the ends of the shaft are turned down to a smaller size for the hangers; for example, an inch and three-quarters shaft will be turned down on the ends to inch and a quarter journals, and the loose pulley nearest to one of these hangers is usually bored the size of the hangers, and the reduced part of the shaft continued far enough to receive the loose pulley as well as the hanger at that end. Countershafts made thus are not well adapted to carry heavy belts, as the reduction of size for

journals and loose pulleys introduces an element of weakness. In order that the loose pulleys should wear well, their hubs are made longer than their face, usually about ¾ of an inch longer on each side from the center than the face of the pulley. In other words, a pulley of 4 inches face would have a hub 5 or 5½ inches long.

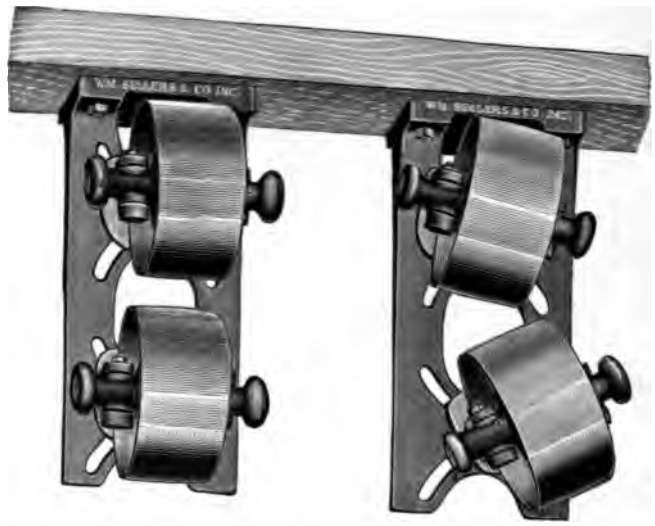
The fast pulley coming next to this one, its hub is reduced in length proportionately, and in case of three pulleys side by side, all of the same width of face for shifting belts, one of the loose pulleys requires to be bored to the same diameter as the shaft itself, and held in its place by a loose collar, fixed by set-screws, while the other end of the hub runs against the hub of the fast pulley that is fast by key or set-screw between the two loose ones. The hubs must be so proportioned as to leave about ⅛ of an inch between the rims of the pulleys to prevent them from striking during revolution.

When the belts are to be shifted, as when three pulleys are to be used, and the pulleys are twice the width of the belts, then these fast and loose pulleys are all turned straight on the face, but when only two pulleys are required, and the belt is practically as wide as the pulley, and the function of the fast and loose pulleys is only to stop and start the machine driven, then those pulleys are turned higher on the face, in order that while driving the belt may be made to keep its place upon the pulley without the assistance of the belt shifting-fork, which guides it.

When these countershafts are used to drive machinery like looms, it has been found disadvantageous to make the pulley which takes the belt from the main shaft, as also the pulley on the main line, large enough in diameter to serve with increased metal in its rim as a fly-wheel to equalize the motion and prevent the knocking off of one loom to seriously affect the ones that are nearest to it. In such case, the fast and loose pulley by means of which the machine is stopped, is usually placed upon the loom, best driven by a wide-faced straight pulley upon the countershaft, and thus may probably be not over 8 or 9 inches in diameter, while the pulley on the line

shaft is made about 24 inches in diameter, with a narrow face to carry about a 2-inch belt, in some cases an inch and a half belt. The receiving pulley upon the countershaft is also made 24 inches in diameter, but with a heavy rim to act as a fly-wheel.

In such case part of the looms will be driven by pulleys, say, of 9 inches in diameter, placed upon the line and to either side; the countershafts will be also fitted with the 9-inch pulleys to drive the looms, the power being transmitted through the larger fly-wheel pulleys on the countershafts.

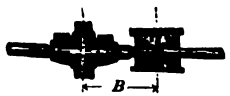


THE BINDER FRAME.

There has lately been introduced quite an extensive line of adjuncts to the shafting appliances that are in some cases made to take the place of countershafts, as, for instance, what is known as the binder frame, a frame or hanger carrying two pulleys running loose upon adjustable shafts one over the other, and so placed by swivelling as to direct the belts from the line shaft that runs lengthwise through the room to fast and loose pulleys on machinery that is actuated by shafts that run across the room at right angles to the

Coupling, or use a Coupling to suit the larger Shaft, with one Cone bored for the smaller Nominal Shaft.

Fig. 3.



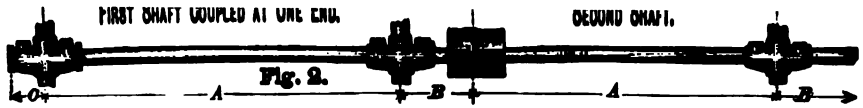


Fig. 2.

...ings on the F... which is the ... lared Shaft.
See Figs. 1 and

Length of Collared End for Fast Collars.	Nominal Size of 1st Shaft.	Nominal Size of 2d Shaft.	1½″	1¾″	2″	2¼″	2½″	2¾″	3″	3¼″	3½″	4″	4½″	5″	5½″	6″	6½″	7″	7½″	8″	Length of Bearing, or Box.	Double C... Vice Coupl... Length.	D
			DISTANCE FROM CENTRE OF BEARING TO END OF SHAFT FOR COUPLING. See B, Figures 1, 2, and 3.																				
3½″	1½″		8½″																		6″	5½″	
4″	1¾″		9″	9½″																	7″	6½″	
4½″	2″		9½″	10½″	11″																8″	7⅝″	
5″	2¼″			11″	11½″	12″															9″	8¼″	
5⅝″	2½″			11½″	12″	12½″	13″														10″	9½″	
6¼″	2¾″			12″	12½″	13″	13½″	14″													11″	10″	
6¾″	3″				13″	13½″	14″	14½″	15″												12″	11″	
7¼″	3¼″				13½″	14″	14½″	15″	15½″	15½″											13″	12″	
7⅞″	3½″				14″	14½″	15″	15½″	16″	16″	16½″										14″	13″	
8 1⅝″	4″				15″	15½″	16″	16½″	17″	17″	17½″	18″									16″	14¼″	1
10″	4½″					16½″	17″	17½″	18″	18″	18½″	19½″	20″								18″	16″	1
11⅛″	5″						18½″	18½″	19″	19½″	20″	20½″	21½″	22″							20″	18″	1
12 3/16″	5½″							20″	20½″	21″	21″	22″	22½″	23½″	24″						22″	19″	1
13¼″	6″							21½″	21½″	22″	22½″	23″	24″	24½″	25″	26″					24″	21″	1
14⅜″	6½″								23″	23½″	24″	24½″	25″	26″	26½″	27½″	28½″				26″	25″	1
15½″	7″									25″	25″	26″	26½″	27½″	28″	29″	30″	30½″			28″	25″	1
16½″	7½″										26½″	27″	28″	28½″	29½″	30″	31″	31½″	32″		30″	28⅝″	1
17¾″	8″											28½″	29½″	30″	31″	31½″	32½″	33″	34″	34½″	32″	28⅝″	1

USE OF TABLE.

Look for size of first Shaft in left-hand column, under the head of size of first Shaft, and in the top line of table, marked size of second Shaft, find the size of the Shaft to be coupled to it. The intersection gives the length B, this added to the length A, or distance from centre to centre of Bearing, and in cases similar to Fig. 2, to the length C, gives the length of the first Shaft, thus: as in Fig. 1. B + A + B = Length. Fig. 2. C + A + B = Length.

main shaft. By means of the binder frame the belt is carried without any disadvantageous twist to these pulleys on the shafts at right angles, placed either in a room above or down to the machines on the floor of the room in which the line shaft is located. The object of this binder frame is to do away with the necessity for what is known as a quarter-twist belt, and I cannot too strongly urge you under no circumstances whatever, unless the belt is a round one, or cord, to ever permit the erection of pulleys requiring a quarter-twist belt, but by careful study to familiarize yourselves with the various means now offered to carry the belt to the work without making more strain upon one edge of the belt than upon the other. The effect of the quarter-twist belt is detrimental in two ways. It causes an end thrust of the shafts against their collar bearing and also wears out the belts with great rapidity, and at the same time is very inefficient in driving.

The whole of this subject of direction in belting has been well illustrated by the working models that have been brought to your notice in the course of your studies. My chief reason for now alluding to it is to show you the great importance of carrying away with you in your minds the instruction that you have received in this direction, as upon a full knowledge of the best practical use of belting your success as designing engineers of that kind of work will depend.

NOTE.—Professor Sellers, in his lecture on "Transmission of Motion by Shafting," gave a general formula for the arrangement of the lengths of each shaft to give room for each coupling near to each hanger, but we have now been furnished with a table prepared by him and used by William Sellers & Co., incorporated, to facilitate the laying out of shafting.

The wood cuts at the head of this table show the position of the hangers and position of couplings, either for the case of extension in both directions from a central head shaft or extension in one direction from that head shaft.

The directions upon this table explain how it is to be used, but it must be borne in mind that all lines of shafting, long or short, must be provided with one pair of shoulders or collars to prevent end motion, and it is recommended to place these collars upon the larger shaft in the line.

When long lines of shafting gradually distribute power by pulleys on each separate length of shaft, the diameters of the shafting may be reduced at intervals, and where shafts of different diameters couple together, it is the usual practice to reduce the end of the larger shaft to the diameter of the smaller one and use a coupling of the larger size, but many engineers prefer to use a coupling of the size of the larger shaft, fitted with a cone at one end for the size of the smaller shaft. The advantage of this latter arrangement is that the shaft may at any future time be extended with a larger size than that put in at first. The particular form of double-cone vice-coupling, which was the invention of Professor Sellers, about 1856, enables the engineer to accomplish the change of size of shaft much more readily than when the ordinary plate couplings are used.

In using a table of this kind to make out a list of shafting it should be observed that instruction should always be given to the shafting maker about the end splines for couplings and also the proper location and length of the middle splines for pulleys and gears.

When it is preferred, loose collars can be furnished by shafting makers, in place of the fixed ones, but when such loose collars are used they should always be arranged with counter-sunk steel set screws. Fixed collars may be readily put in place by shrinking them onto the shaft after enlargement of the collar by heat. Collars are also to be had split in halves and bolted together so as to clasp the shaft firmly at any desired point. These can be detached or moved without disturbing the shafting.

ON THE HEAT OF DISSOCIATION OF AMMONIA IN REFRIGERATING MACHINES OF THE ABSORPTION TYPE.

BY PROFS. J. E. DENTON AND D. S. JACOBUS.

(Continued from Page 32).

THEORETICAL DEDUCTION INDICATING THAT IF THE HEAT OF THE DISSOCIATION OF AMMONIA IS CONSTANT, AS IS ASSUMED BY LEDOUX, THERE WILL BE REQUIRED ABOUT FIVE PER CENT. OF ENTRAINED WATER IN THE AMMONIA, IN ORDER THAT ALL THE HEAT EQUATIONS SHALL BE SATISFIED. ALSO DEDUCTIONS SHOWING THAT IF THERE IS NO WATER ENTRAINED IN THE AMMONIA, THE HEAT OF DISSOCIATION AT A HIGH TEMPERATURE WILL BE GREATER THAN THAT AT A LOW TEMPERATURE.

CASE I. ASSUMING FIVE PER CENT. OF WATER CARRIED OVER BY THE AMMONIA.

Receiver.—The gauge pressure is 137.6 lbs. per sq. in., the temperature corresponding to which is 80° Fahr.

The quantity of water in the liquid, in order that it should be 5 per cent. of the total weight, is, $\frac{m}{19}$, in which m is the weight of ammonia.

To determine the amount of gas vaporized in passing through the throttling cock, we must form an equation that expresses the fact that the heat in the liquid entering the cock is the same as the heat in the liquid and vapor after passing through the cock. To find the heat in entering liquid, Ledoux assumes that it will be the sum of the heat in a saturated solution of ammonia containing the amount of water present, plus the heat in a weight of anhydrous ammonia, equal to the difference of the entire weight and the calculated weight of saturated ammonia.

Let m' = weight of ammonia in the saturated aqua ammonia then we have $m' = \frac{m}{19} \times \frac{\beta'}{v' \times 62.4}$ in which β' is the co-efficient of solubility, and v' the volume of one pound of saturated ammonia gas at the temperature of the condenser.

Carius gives an equation for solubility which, when reduced to English units, is:

$\beta = 1841.6 - 34.8\ t + .366\ t^2 - .00164\ t^3$ in which $t =$ temperature in degrees Fahr.

If β' is the value for $t' = 80°$, which is the temperature of the condenser, we have $\beta' = 560$. We also have $v' = 2.05$ hence:

$$m' = m \frac{560}{19 \times 2.05 \times 62.4} = .230\ m.$$

Cooler.—Let the quantity of gas retained in the water on entering the cooler, which is at a pressure of 25.7 pounds, so that the corresponding temperature is 13° Fahr., be m'', then employing a similar notation to that used in the case of m', we have—

$$m'' = \frac{\beta''}{19 \times v'' \times 62.4} \times m$$

$v'' = 7.04$

$\beta'' = 1447$

$$m'' = \frac{1447}{19 \times 7.04 \times 62.4}\ m = .173\ m$$

The equation given by Ledoux is

$$(m-m')\ x_2\ r_2 + (m'-m'')\ S_2 = (m-m')\ (q_1' - q_2) + w\ (q_{e_1}' - q_{e_2}) + m'\ c_p\ (T_1' - T_2)$$

In which

$(m - m')\ x_2 =$ weight of liquid vaporized in passing through the throttling cock.

$w =$ weight of water $= \frac{m}{19}$. $S_2 =$ heat of dissociation.

$q_{e_1}' - q_{e_2} =$ difference of heat in water at 68°, the temperature to which the liquid is cooled before entering the throttling cock, and 13°, the temperature of the mixture after passing through the throttling cock, = 55 B. T. U.

$r_2 =$ latent heat of ammonia at the temperature of the cooler.

Performing the operations indicated in the equation we have:

$$w\,(q_e'_2 - q_{e2}) = m \times \frac{55}{19} = 2.9\,m$$

$$m'\,c_p\,(T_1' - T_2) = .230 \times .508 \times 55 \times m = 6.4\,m.$$

$$m - m' = (1 - .230)\,m = .770\,m.$$

$$(m - m')\,(q_1' - q_2) = .770\left[39.46 - (-18.38)\right] m$$

$$= .770 \times 57.84\,m$$

$$= 44.5\,m$$

$$(m - m')\,x_2\,r_2 = .770\,m\,x_2 \times 578.0$$

$$= 445.\,m\,x_2$$

S_2, by value of Favre and Silbermann, is 926 B. T. U.* Employing this figure we have $(m'—m'')\,S_2 = .057\,m \times 926 = 52.8\,m$.

Collecting the above values of the equation we have

$$445.0\,m\,x_2 + 52.8\,m = 44.5\,m + 2.9\,m + 6.4\,m$$

$$x_2 = \frac{1}{445} = .2\%$$

$$(1 - x_2) = .998 = 99.8\%$$

The heat Q imparted to the ammonia at the cooler is given by the equation

$Q = (1 - x_2)\,(m—m')\,r_2 +$ (Heat required to superheat the gas) + (weight of ammonia separated from the aqua ammonia by the superheating) $\times\, S_2$†.

The value of $(1 - x_2)\,(m - m')\,r_2$ is

$$.998 \times .770\,m \times 578 = 444.0\,m$$

The gas is superheated from its temperature of saturation, 13° Fahr. to 30° Fahr.; hence, the heat required to superheat it is $17 \times .508\,m = 8.64\,m$.

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*This value has been practically verified in experiments made at the Stevens Institute of Technology. It is also within 2½% of the value determined by Dr. Hans von Strombeck, Journal of Franklin Institute, January, 1891.

†This equation assumes that the water is carried from the cooler to the absorber in the form of a spray so that it does not part with its latent heat of evaporation.

Let m''' be the weight of ammonia retained in the water leaving the cooler, then we have

$$m''' = \frac{\beta'''}{19 \times v''' \times 62.4}$$

β''' = co-efficient at 30° Fahr. = 1083

$$m''' = \frac{1083\, m}{19 \times 7.04 \times 62.4} = .130\, m$$

Weight of ammonia separated from aqua ammonia by superheating = $(.173 - .130)\, m = .043\, m$.

Heat to dissociate ammonia = $926 \times .043\, m = 39.8\, m$

The sum is $(444.0 + 8.6 + 39.8)\, m = 492.4\, m$

Experiment indicates that this heat is equal to

500,010 + 1,920 = 501,930 B. T. U. per hour, so that the weight m per hour, is—

$$\frac{501{,}930}{492.4} = 1{,}019 \text{ lbs.}$$

Generator.—A small portion of the ammonia and entrained water that passes from the generator to the condenser is condensed at the highest temperature of the condenser and returned to the generator. This is called the drip liquor. The object of returning the drip liquor is to remove as much water as possible from the ammonia. The drip liquor enters the top of the generator, or analyzer, at a point near to that at which the strong liquor from the absorber is returned, so that it must be treated in a similar manner to the latter.

The heater, which has been considered as part of the generator, is situated above the generator. In this the weak liquor parts with a portion of its heat in heating the strong liquor. Considering the heater a portion of the generator, we have for the heat imparted to the generator:

1st. Heat to dissociate the weight $(m + m_1)$ of gas, m_1 being the weight of gas returned with the drip liquor.

2d. Heat to evaporate $\frac{m}{19}$ lbs. of water from the temperature of the absorber to steam at the temperature it leaves the generator.

3d. Heat to evaporate the water that is returned with the weight of ammonia, m_1, in the form of drip liquor from the temperature of the drip liquor to steam at the temperature of the generator.

4th. Excess of heat contained in the weak liquor that leaves the heater over that contained in an equal quantity that enters the heater, together with the weight m of ammonia. In other words, this is the excess of heat in the weak liquor leaving the heater over that contained in the strong liquor, if the heat in the weight m of ammonia in the strong liquor is deducted.

5th. Heat required to elevate the temperature of the weight m of ammonia gas from the temperature at which it is returned to the absorber to the temperature at which it leaves the generator.

6th. Heat required to elevate the temperature of the weight m_1 of ammonia gas in the drip liquor to the temperature of the gas leaving the generator.

7th. Heat lost by radiation.

That the sum of the above quantities of heat is equal to that imparted to the generator may be proved as follows:

The gas is dissociated at different temperatures. That which is first dissociated near the top of the analyzer is at a lower temperature than that which is dissociated when the liquor becomes weak. The heat S required to dissociate a unit weight of gas is, in the absence of other data, considered by Ledoux, to be constant. We will also adopt this supposition. Let an elementary weight of the gas be dissociated at the temperature of $t°$. Let t_1 be the temperature of the strong liquor entering the generator. Let c_1 be a specific heat quantity such that if the ammonia that is dissociated from the solution be multiplied by this quantity and by the range of temperature, and this amount added to the heat imparted to the remaining solution that carries the ammonia, considering it to have a constant specific heat c_2, the sum will be the entire heat imparted to the mixture. The heat imparted to each elementary weight of the mixture of ammonia and water in heating it up to the temperature at which dissociation occurs, will be

$$(c_1 w + c_2 W)\ (t - t_1)$$

W, being the weight of the solution that carries the weight w of ammonia, c_2 its specific heat, and t_1 the temperature of the mixture entering the generator. The above quantity $+ wS$ gives the total heat required to heat the solution to the temperature t and dissociate the gas.

The gas does not pass out of the generator at the temperature t_1 but in ascending it parts with a portion of its heat, and thus aids in dissociating some of the gas at a lower temperature than itself. The amount of heat given up in this way is

$$Cp\ w\ (t - t_2)$$

Cp being the specific heat of the gas at a constant pressure, and t_2 the temperature of gas leaving the generator.

The heat imparted to the weight W of water after the gas is dissociated is

$$c_2\ W\ (t_3 - t)$$

t_3 being the temperature at which the weak liquor leaves the generator.

The total heat imparted at the generator to each portion of the solution that brings in the weight of gas w is, therefore,

$$wS + (c_1 w + c_2 W)\ (t - t_1) - Cp\ w\ (t - t_2) + c_2\ W\ (t_3 - t)$$

which reduces to

$$wS + c_1 w\ (t - t_1) - Cp\ w\ (t - t_2) + c_2\ W\ (t_3 - t_1) \ldots\ldots (A)$$

As all the elementary weights in passing away from the generator are similarly circumstanced, they contain the same amount of heat, and as this is also the case of the weights on entering the generator, the amount of heat imparted to each equal portion of the solution containing the elementary weight w, in passing through the generator, will be the same. The elementary weights are dissociated at various temperatures, and as the heat imparted to each is the same, it does not depend on the temperature of dissociation.

The value of equation (A) will therefore be constant for any value of t. To accomplish this, c_1 must be equal to Cp, hence the ession becomes

$$Cp\ w\ (t_2 - t_1) + c_2\ W\ (t_3 - t_1) \ldots\ldots\ldots\ldots\ldots\ldots (B).$$

Or, the heat imparted will be that to elevate the temperature of W from t_1 to t_3, considering the specific heat constant at c_3 + the heat imparted to the weight w of ammonia, considering it as a gas, so that the quantity of this heat is measured by the range of temperature × the specific heat at constant pressure.

In the summation of the various quantities of heat furnished by the generator, the 1st, 4th, 5th and 6th quantities are given by equation (B). The 2d and 3d quantities relate to the moisture carried over with the ammonia, and are readily obtained with the aid of a table of the properties of saturated steam.

NUMERICAL VALUES OF QUANTITIES OF HEAT IMPARTED AT THE GENERATOR.

In the numerical deductions the values given in Zeuner's table of the properties of saturated ammonia are employed.

The value of the 1st quantity is:

$$(m + m_1)\, S = 926\, (m + m_1)$$

$m = 1019 \therefore (m + m_1)\, S = 943{,}590$ B. T. U. $+ 926\, m_1$

The value of the 2d is:

$$\frac{m}{19}\left(1175 - 132\right) = 54.9\, m = 55940 \text{ B. T. U.}$$

The value of 3d:

Assuming the drip liquor to be one-third ammonia, and that it is returned at 100° Fahr., we have*

$$2\, m_1\, (1175 - 100) = 2150\, m_1{}^\circ.$$

Value of 4th quantity:

The weight of the weak liquor per pound of ammonia must be determined in order to calculate the value of this quantity. This weight may be calculated as follows:

The weak liquor parted with 94° Fahr. in raising the temperature of the strong liquor 80° Fahr. The loss of heat by radiation

* The assumptions here made in regard to the temperature and per cent. of ammonia in the weak liquor returned to the generator, tend to give as low a result as is probable for the per cent. of drip liquor. In other calculations which follow, assumptions are made which tend to give the highest results, and it is shown that the two results are very nearly the same.

is about 2,000 B. T. U. per hour. As the calculated weight of weak liquor is 7,200 pounds per hour, the loss of temperature due to radiation will be 0.3° Fahr. This loss is less than the probable error of the range of temperatures, and will therefore be neglected. The weak liquor contains by analysis 12½ per cent. of ammonia. Assuming the heat of the mixture to be the same as that contained in equal weights of water and anhydrous ammonia, and taking the specific heat of the anhydrous ammonia at 1.3*, we have for the specific heat of the weak liquor, $1.3 \times .125 + .875 = 1.04$.

Let the strong liquor contain the proportion by weight x of ammonia, then we have for its specific heat,

$$1.3\,x + (1 - x).$$

If y be the ratio by weight of the weak liquor to the weight of ammonia circulated through the coils, we have:

$$x = \frac{.125\,y + 1}{y + 1} \qquad (A)$$

We also have:

$$1.04 \times 94.0\,y = \left\{ 1.3\,x + (1 - x) \right\} 80\,(y + 1),$$

$$\text{or } x = \frac{97.76\,y}{24\,(y + 1)} - 3.333 \qquad (B)$$

Combining equations (A) and (B) we have:

$$y = 7.$$

This gives $x = 23\frac{1}{2}\%$†

Employing the value of $y = 7$ and the specific heat of the weak liquor = 1.04, we have for the value of the 4th quantity

$$1.04 \times 7\,m \times (178 - 132) = 334.9\,m = 341260 \text{ B. T. U.}$$

* This figure is based on the experimental results obtained by Dr. Strombeck. See Journal of the Franklin Institute, 1890, Vol. 2, p. 471, which gives 1.23 for the average specific heat between the temperatures of 85° and 142° Fahr. As the average temperatures in the heater are in the neighborhood of 200° Fahr., a correction has been made at the rate of increase due to temperature given by the theoretical formula. The theoretical specific heat is nearly the same as that obtained in Dr. Strombeck's experiments.

† This result agrees with an approximate analysis made on the strong liquor which was found to contain, in round numbers, 25 per cent. of ammonia.

The value of the 5th quantity is:

$m\ (200 - 132) \times .508 = 34.5\ m = 35160$ B. T. U.

The value of the 6th is:

$m_1\ (200 - 100) \times .508 = 51\ m_1$.

The value of the 7th quantity is given on page 20.

The various quantities of heat imparted per hour are:

1st.	943590 B. T. U.	$+ 926\ m_1$
2d.	55940 "	
3d.		$2150\ m_1$
4th.	341260	
5th.	35160	
6th.		$51\ m_1$
7th.	7750	
	1383700	$+ 3127\ m_1$

The heat given up by the steam to the generator is by measurement = 1465500 B. T. U.

The difference between this amount and 1383706 "

is 81794 "

which must equal $3127\ m_1$.*

Hence $m_1 = \frac{81794}{3127} = 26$ pounds per hour.

The weight of the drip liquor per hour under the assumed conditions will therefore be $26 \times 3 = 78$ pounds, which is about $7\frac{1}{2}\%$ of the ammonia circulated through the cooler.

If the weight of ammonia in the drip liquor be $\frac{3}{4}$ of the entire amount, and the temperature at which it is returned to the generator is 175°, the value of the 3d quantity becomes $\frac{1}{3}\ m_1\ (1175 - 175) = 333\ m_1$ and the value of the 6th quantity,

$m_1\ (200 - 175) \times .508 = 12.7\ m_1$. Hence,

$(926 + 333 + 12.7)\ m_1 = 81794$,

and $m_1 = 64$ pounds per hour.

Hence the weight of drip liquor per hour will be $64 \times \frac{4}{3} = 85$ pounds, which is about $8\frac{1}{3}$ per cent. of the ammonia circulated.

If the temperature of the drip liquor be 100 degrees, and it contains 50 per cent. of ammonia, the amount of drip will be about 8 per cent. of the ammonia circulated.

* This difference is affected by all the errors involved.

It may be observed, therefore, that the extreme range of probable assumptions in regard to the temperature at which the drip liquor is returned to the generator, and in regard to the percentage of ammonia it contains, alters the calculated quantity of drip liquor less than 1 per cent. of the weight of ammonia circulated. In the calculations which follow, we have, therefore, worked out only the mean value of this quantity.

CASE 2. NO WATER CARRIED OVER WITH THE AMMONIA.

Receiver.—Ledoux's equation for the amount of ammonia vaporized in passing through the throttling cock reduces to

$$m x_2 r_2 = m (q'_1 - q_2)$$

which gives $x_2 = \frac{q'_1 - q_2}{r_2} = \frac{57.86}{578} = 10\%$

$$1 - x_2 = 90\%$$

Cooler.—The heat imparted to the ammonia will be

$$Q = (1 - x_2) r_2 m = (.9 \times 578) m = 520.2 m.$$

Heat to superheat the gas from 13° to 30° Fahr. $= 8.6 m$.

Total heat imparted to cooler $= 520.2 + 8.6 = 528.8$ B. T. U.

Weight of ammonia per hour $= \frac{501,930}{528.8} = 949$ lbs.

Generator.—The heat required at the generator is divided as follows:

1st.—Heat to dissociate the weight m of gas $= 926 \times 949 =$ 878,770 B. T. U. per hour.

2d.—Heat to dissociate the weight m_1 of ammonia gas contained in the drip liquor $= 926 m_1$.

3d.—Heat imparted to weak liquor $= 1.04 \times 7 m \times (178 - 132)$ B. T. U. per hour $= 317,800$ B. T. U.

4th.—Heat to heat the weight m of gas from 132° to 200° $= 949 \times 68 \times .508 = 32,780$ B. T. U.

5th.—Heat required to heat the weight m_1 of gas from 100° to 200° $= 51 m_1$.

6th.—Heat to evaporate water returned in drip liquor $= 1,075 m_1$.

7th.—Heat lost by radiation.

The various quantities of heat imparted per hour are, therefore,

1st,	878,770	B. T. U.	
2d,			926 m_1.
3d,	317,800	"	
4th,	32,780	"	
5th,			51 m_1.
6th,			1,075 m_1.
7th,	7,750	"	
	1,237,100	"	+ 2,052 m_1.
Observed quantity =	1,465,500		
Difference =	228,400		

$$m_1 = \frac{228,400}{2,052} = 111 \text{ lbs. per hour}$$

The weights of drip liquor per hour under the assumed conditions will, therefore, be $111 \times 2 = 222$ lbs., which is about 23% of the weights of ammonia circulated through the cooler.

CASE 3. HEAT OF ABSORPTION REQUIRED TO PRODUCE A BALANCE OF HEAT UNITS IF NO WATER IS CARRIED OVER WITH THE AMMONIA AND THE DRIP LIQUOR IS 10% OF THE WEIGHT OF AMMONIA CIRCULATED THROUGH THE COOLER AND CONTAINS 50% OF AMMONIA.

The values of the several heat quantities would be—

$$m_1 = 47.4$$

1st.	$S \times 949$	
2d.	$S \times 47$	
3d.	317,800	B. T. U.
4th.	32,780	"
5th.	2,410	"
6th.	50,950	"
7th.	7,750	"
	$S \times 996 +$ 411,690	B. T. U.

This must equal the heat imparted, or

	1,465,500	B. T. U.
	411,690	"
Hence, $996\,S =$	1,053,810	"
$S =$	1,058	B. T. U.

PROPERTIES OF THE SATURATED VAPOR OF AMMONIA.

BY PROF. DE VOLSON WOOD.

ABOUT two years since, I computed a table of some of the properties of the saturated vapor of ammonia. The formulæ were my own, deduced from hypotheses of Rankine, and Regnault's experiments were used to find numerical values. Regnault made experiments to determine the pressure corresponding to the temperature of the saturated vapor, and also the relation between the pressure and volume of the superheated vapor (or gas) at the constant temperature of 8.1° Cent.

It will be interesting to note the degree of accuracy of my table, when compared with direct experiment.

Dr. Von Strombeck, chemist, found by direct experiment that the latent heat of vaporization of ammonia ($N H_3$)

At 32.45° Fahr., was	534.2	heat units.
My table gives	535.18	"
Difference	0.98	"

Professor Jacobus found that Regnault had made a determination of this constant, and after a somewhat elaborate investigation concludes that Regnault's experiments give

At 53° Fahr	521.64
My table gives	522.39
Difference	0.75

According to these results my table is practically exact. No table founded on the results of experiment will be theoretically exact. All experiments are subject to residual errors, and, in this case, the formulæ are provisional—or, in other words, are somewhat empirical, and it is too much to expect that they will give results strictly correct. The results of experiments of Von Strombeck and the reductions by Professor Jacobus are, at best, very probable values. Still, it is gratifying to all parties that the results, independently obtained, agree so nearly. I think it may be said, with confidence, that my table of the properties of the saturated vapor of ammonia is the most reliable of any now known.

THE ORE-DRESSING AND SMELTING WORKS AT CASAPALCA, PERU.

BY OTTO F. PFORDTE, M. E., '86.

CASAPALCA is situated in Peru on the Oroya Railroad, the lower terminus of which is the Port Callao. The altitude above sea level of Casapalca is very nearly 14,000 feet, consequently the climate is rather cold and severe, especially during the dry or winter season, which ends about the beginning of November. Agriculture is not carried on at this altitude, where vegetation is but scanty, its limit being at about 12,000 feet. The timber limit in the valleys is at the same altitude. Continuing upward from Casapalca the passes over the Andes Mountains are reached in about two hours riding on horseback, and at an altitude of about 16,300 feet, at which places perpetual snow and gigantic glaciers are passed within a short distance. In the neighborhood of Casapalca are many mines, which in former times have furnished, and many of which still furnish, an abundance of good silver ores, comprising mostly galena, copper, and iron pyrites, gray copper ore, zinc-blende, and oxidized ores, which latter are called *pacos* by the natives. Many of the larger mines had been worked by the Spaniards before the War of Independence in Peru, in 1821, and judging from the old workings, large quantities of ore must have been taken from them. At present, operations have been resumed with varying success in quite a number of the mines, but only such ores which could yield some profit with the high cost of transportation were utilized, while all the remainder were thrown on the dump. These dumps, therefore, often included such ores that could be utilized by the

introduction of proper machinery, and it was with this object in view that an establishment of this kind was erected.

The dump of the Rayo Mine, in the neighborhood, assays from 15 to 25 ounces per ton, and is situated about 1,000 feet above the works; the ore is lowered by means of cable cars and a brake. Other ores are brought in on llamas, which take 100 pounds at a load. The ore from the dumps on the works is passed on a grate, having the bars nearly an inch apart, the material remaining on the bars, passed through an ore crusher, crushing down to about 1½ inch. Below the ore crusher is an ore bin, holding 10 to 12 tons, in which the fine and crushed ores unite, and from which they pass into a Hendy feeder, and after that into a 5-stamp battery. These stamps weigh 750 pounds each, have a 7-inch drop, make 90 drops per minute, and crush about 135 tons in 6 days, 24 hours each, through a 12-mesh screen. The pulp passes by an automatic sampler, for taking the daily pulp sample, and then through a launder into a Spitz-Kasten, which may be described as an inverted pyramid, with a current of clear water entering at the apex. This current is regulated so as to allow the coarser and heavier particles to pass down and out into a separate launder, while the lighter portions float off at the top passing through a launder into a large settler. The coarser parts run into a three-compartment jig with 12 or 14 mesh screens, through which the product passes into the lower part, from which it is drawn off from time to time. The tailings overflowing the last jig compartment pass into a hexagonal revolving 40-mesh screen, and the fine material passing through the same is united with the other fine matter in the settler. The product of the jigs, consisting of iron and copper pyrites, gray copper galena and zinc-blende, is weighed, sampled and dried. The fine material drawn from the lower part of the settler passes upon two Vrue vanners, one of which has a plain, the other a corrugated belt, the product of the latter being larger in quantity and lower in quality than that of the former, but on the whole being more advantageous, as a higher money-value and cleaner tailings are produced.

The tailings from the vanners pass upon a double-deck round buddle of about 15 feet diameter, from which another product, though of lower grade, is obtained, and finally the tailings of the buddles pass out into the stream. The combined product of the jigs, vanners and buddles average about 10 tons of concentrated ore per week, containing about 1,500 ounces of silver, with a small percentage of lead and copper.

The motive power is furnished by a 125 horse-power turbine with 35 feet of head. An electric light plant furnishes the required light at night, and a well-equipped laboratory is adequate for all necessary assay and analytical work.

The further treatment of the product obtained in concentration is continued in a reverberatory, and then in a water-jacket furnace.

All the concentrates obtained from the jigs are well mixed, and assay about 158 ounces silver per ton. The products of the two vanners are also mixed, and assay about 209 ounces per ton. All concentrates contain a little lead from 6 to 12 per cent. and perhaps 3 to 5 per cent. of copper.

Furthermore, a third class of material in the shape of pulverized galena with about 45 per cent. of lead and 50 ounces per ton of silver is well mixed in the proportion of two to one with each of the two above-mentioned classes, and then charged in 1-ton charges into the reverberatory furnace where each charge remains for six hours for the purpose of roasting and slagging. The fuel per charge, consists of about 300 pounds of soft coal and 250 pounds of *taquia*, as the dried dung of the llamas is called. The product is a well-roasted and sintered or slagged ore, containing nearly all the metallic substances in the form of silicates. Sometimes a little copper or lead matte, or even lead bullion, were produced, which then were generally quite high in silver.

The slagged ore was withdrawn from the furnace, cooled and broken into pieces from two to four inches across, and formed the principal portion of the charge for a small 10-ton water-jacket furnace having a jacket 2 feet diameter and 3 feet high.

An analysis of the slagged ore gave the following result:

SiO_2	17.2 per cent.
Cu	9.3 "
Fe_2O_3	22.5 "
CaO	6.0 "
Pb (assay)	34.5 "
S	6.5 "
Ag	.34 "
	96.34

The material charged into the water jacket each day varied frequently, but may be taken to consist of 18,000 pounds of above-mentioned slagged ore, 500 pounds of old slags found on ancient smelting works, averaging 45 per cent. Pb and 2 to 5 ounces of Ag per ton; 300 to 500 pounds of oxidized ores, 1,500 pounds of limestone, 1,000 pounds of bog iron and 1,500 pounds of dirty slags, containing from 8 to 12 per cent. Pb. The shipping products were lead bullion, assaying 235 ounces per ton, and copper or lead matte, of which two assays gave:

Matte.	No. 1.	No. 2.
Pb	61 per cent.	7 per cent.
Cu	27 "	50 "
Ag	38 ounces per ton.	150 ounces per ton.

The slag of the water jacket, whenever it was more than 6 per cent. Pb, was recharged, and with less lead, it went on the dump. The following is the analyses of a fair slag:

SiO_2	37 per cent.
Fe_2O_3	50.2 "
CaO	8.6 "
Pb	3.4 "
	99.2

The fuel used in the water jacket generally consists of English coke, which placed on the ground costs about $40 per ton, and the the proportion used in the furnace is about one ton to every six or seven tons of charge. The soft coal used in the reverberatory is native, and costs about $16 per ton. Coking coal is also found in Peru, though at a greater distance than the soft coal; good coke

being made from it, and utilized at other smelting establishments. Wood and charcoal are very expensive.

' A large Brückner revolving furnace and a 30-ton water jacket have been added to the works since, whereby the capacity is largely increased.

The labor employed consists almost exclusively of Indians, who are the degraded descendants of the great Inca race that occupied the entire country before its conquest by the Spaniards. These people still speak their own language, the Quichua, and almost all possess little farms in the interior agricultural regions, working in the mines about one half of the time, and earn from 40 to 60 cents per day. Their principal failing is their great weakness for alcoholic stimulants. Their nourishment and dwelling huts are very poor, and they seem to lack all desire for improving their condition.

AN EXTENSION OF "GRAINS PER GALLON" IN WATER ANALYSES

BY DURAND WOODMAN, PH. D., '80.

IN the course of work done at different times in relation to water for manufacturing operations, boiler supply, etc., some computations have been made, which when collected in tabular form, may prove of use to others.

It has occasionally been necessary to make somewhat detailed calculations of the total content of certain mineral matters in large volumes of water, and to convert a water analysis expressed in parts per 100,000, or in grains per gallon, to pounds per 1,000 gallons, or pounds per 1,000 pounds water. Those versed in technical and chemical matters sometimes overlook the fact that others who have not had similar advantages are not always able to derive the full benefit intended from technical work.

For example, a water analysis expressed in grains per gallon may not give as definite an idea as could be desired, of the importance of certain facts developed and bearing on a particular problem.

The statement that a water contains so many grains common salt per gallon, conveys but a very vague idea unless reasonably accurate conceptions exist in the mind, both of the weight and volume of the quantities in question. In this instance one quantity may be considered as known, and the other as unknown, since those familiar with different quantities of water expressed in gallons have, as a rule, nothing to do with "grains." This has led me in numerous instances to append special computations intended to bring out at a glance, in more tangible terms the facts of a technical water analysis. Of the three measures of weight; grains, ounces and pounds; the last exists with the greatest degree of accuracy in the greatest number of minds, and for the purpose of quickly converting analytical results expressed in "grains per gallon," into pounds, the following table (I) is given:

TABLE I.—*Grains per Gallon to Pounds per* 100 *U. S. Gallons, Etc.*

Grains per Gallon.	Pounds per 100 Gallons.	Pounds per 100 Pounds Water.
1	0.228571	.002743
2	0.457142	.005486
3	0.685713	.007229
4	0.914284	.010972
5	1.142855	.013719
6	1.371426	.016458
7	1.599997	.019201
8	1.828568	.021944
9	2.057139	.024689

A 100 horse-power boiler evaporates 30,000 pounds of water in 10 hours, which amounts to 390 tons per month of 26 working days. (*Fuel and Water*, Schwackhöfer.)

Accepting this statement as sufficiently accurate for present purposes, we should have for the following waters the quantities of dissolved mineral matter shown in Table II.

TABLE II.—*Dissolved Mineral Matter Contained in Daily and Monthly Feed-Water of a* 100 *Horse-Power Boiler Evaporating* 360 *Gallons per Hour.*

SOURCE.	MINERAL MATTER.		MINERAL CONTENT IN	
	Milligrams per Litre.	Grains per Gallon.	10 Hours' Feed = 3600 Galls. = *30,000 Lbs	30 Days' Feed = 108,000 Galls. = *900,000 Lbs.
Croton water. (Wurtz and Woodman, *Eng. & Min. Jr.*, April 26, 1890)	54.	3.1	11,160 grs. = 25.5 lbs	765. lbs.
Passaic River. (W. & W., *ibid.*)	76.	4.4	15,840 grs = 36.1 lbs.	1.083 lbs.
Artesian well, 225 feet. (Mechanic Street, Newark, N. J. D. Woodman)	710.	41.52	149,472 grs. = 342. lbs.	10.250 lbs.
Artesian well, 350 feet deep. Harrison, N. J. (D. W.)	860	50. +	180,000 grs. = 411.4 lbs.	12.342 lbs.
Sea water. (Approx.)	34,000 ±	2,000 ±	7,200,000 grs. = 16.457 lbs.	493.710 lbs.

* These weights are the nearest round numbers. The exact figures are 29,988 and 899,640, respectively.

From the tables we may obtain the mineral matter contained in 1,000,000 gallons of these waters.

MINERAL MATTER IN TONS, PER MILLION GALLONS.

Croton water	3.5	tons per	million	gallons.
Passaic water	5.0	"	"	"
Artesian well, Mechanic Street, Newark (250 feet)	47.4	"	"	"
Artesian well, Harrison, N. J., (350 feet)	57.2	"	"	"
Sea water, (approx)	2,288	"	"	"

The analysis of the artesian well water at Harrison (depth 350 feet), was as follows:

ARTESIAN WELL WATER AT HARRISON, N. J.

	Grs. Per Gallon.
Na_2O	3.83
K_2O	0.81
CaO	15.39
MgO	8.12
SiO_2	.92
$Fe_2O_3 + Al_2O_3$	.69
SO_3	20.06
Cl	4.30
CO_2 (calculated)	7.87
Organic	.98
	62.97

Whether the quantity of calcium sulphate be obtained by combining the Ca with the SO_3 left over from the alkalis after they have been combined with all the chlorine present; or whether the maximum quantity of $CaSO_4$ from the Ca and SO_4 present be computed, the difference in this instance is under two grains, and the lower figure is given.

	Grs. Per Gal.	Lbs. Per 100 Gals.
NaCl	7.115	1.63
K_2SO_4	1.520	0.34
$CaSO_4$	33.124	7.57
$MgSO_4$	2.680	0.62
$MgCO_3$	15.274 (?)	3.48

In a day of 10 hours a 100-horse-power boiler, using 3600 gallons of this water, would contain 272.5 pounds of calcium sulphate. Sea water, with about 81. grains of $CaSO_4$ per gallon, would give about 666. pounds $CaSO_4$ at the end of a day's run

The tabulation of gross results in this way often calls attention to points connected with special problems, which the mind fails to notice unless relieved of the efforts at intermediate calculation caused by dealing with small units.

WATER ANALYSIS.

TABLE SHOWING THE NUMBER OF GRAINS PER U. S. GALLON (58,318 GRAINS) AND IMPERIAL GALLON (70,000 GRAINS) CORRESPONDING TO MILLIGRAMMES PER LITRE. BY THOS. B. STILLMAN.

Milligrammes per Litre.	Grains per Imperial Gallon.	Grains per U. S. Gallon.	Milligrammes per Litre.	Grains per Imperial Gallon.	Grains per U. S. Gallon.
1	0.0700	0.0583	51	3.5700	2.9742
2	0.1400	0.1166	52	3.6400	3.0325
3	0.2100	0.1749	53	3.7100	3.0908
4	0.2800	0.2332	54	3.7800	3.1491
5	0.3500	0.2915	55	3.8500	3.2074
6	0.4200	0.3499	56	3.9200	3.2658
7	0.4900	0.4082	57	3.9900	3.3241
8	0.5600	0.4665	58	4.0600	3.3824
9	0.6300	0.5248	59	4.1300	3.4407
10	0.7000	0.5831	**60**	4.2000	3.4990
11	0.7700	0.6414	61	4.2700	3.5573
12	0.8400	0.6998	62	4.3400	3.6157
13	0.9100	0.7581	63	4.4100	3.6740
14	0.9800	0.8165	64	4.4800	3.7323
15	1.0500	0.8747	65	4.5500	3.7906
16	1.1200	0.9330	66	4.6200	3.8489
17	1.1900	0.9914	67	4.6900	3.9073
18	1.2600	1.0497	68	4.7600	3.9656
19	1.3300	1.1080	69	4.8300	4.0239
20	1.4000	1.1663	**70**	4.9000	4.0822
21	1.4700	1.2246	71	4.9700	4.1405
22	1.5400	1.2829	72	5.0400	4.1988
23	1.6100	1.3413	73	5.1100	4.2572
24	1.6800	1.3996	74	5.1800	4.3155
25	1.7500	1.4579	75	5.2500	4.3738
26	1.8200	1.5162	76	5.3200	4.4321
27	1.8900	1.5745	77	5.3900	4.4904
28	1.9600	1.6329	78	5 4600	4.5488
29	2.0300	1.6912	79	5.5300	4.6071
30	2.1000	1.7495	**80**	5.6000	4.6654
31	2.1700	1.8078	81	5.6700	4.7237
32	2.2400	1.8661	82	5.7400	4.7820
33	2.3100	1.9244	83	5.8100	4.8403
34	2.3800	1.9828	84	5.8800	4.8987
35	2.4500	2.0411	85	5.9500	4.9570
36	2.5200	2.0994	86	6.0200	5.0153
37	2.5900	2.1577	87	6.0900	5.0736
38	2.6600	2.2160	88	6.1600	5.1319
39	2.7300	2.2745	89	6.2300	5.1903
40	2.8000	2.3327	**90**	6.3000	5.2486
41	2.8700	2.3910	91	6.3700	5.3069
42	2.9400	2.4493	92	6.4400	5.3652
43	3.0100	2.5076	93	6 5100	5.4235
44	3.0800	2.5659	94	6.5800	5.4818
45	3.1500	2.6243	95	6.6500	5.5402
46	3.2200	2.6826	96	6.7200	5.5985
47	3.2900	2.7409	97	6.7900	5.6568
48	3.3600	2.7992	98	6.8600	5.7151
49	3.4300	2.8575	99	6.9300	5.7734
50	3.5000	2.9159	**100**	7.0000	5.8318

EXAMINATIONS.

BY PROF. DE VOLSON WOOD.

SOME instructors, seeing the evils of examinations, would abolish them entirely; others, recognizing the stimulus that may be made of them, overdose the subject. There is a mean between these that is desirable. I have known cases where the chief object of the examination was to mark the end of a course or term, at which it was absolutely necessary for the student to be present, but not necessary to exhibit any knowledge of the subject in order to "pass." This may serve to keep the student to the last day of the term, but belittles the examination, making it of little or no profit.

An examination, to be of value, must have an ulterior object; there is no pleasure and little profit in holding it simply for its own sake. If, in a graded course, its object be to weed out the unsuccessful, it may, as a rule, be confined to a comparatively few of the weaker ones, all the better ones being excused. This plan has been used by several professors in the Institute. The writer has tried it, and abandoned it. It has the advantage of enabling the instructor to confine his attention to a comparatively small number, and thus may enable him to discriminate more closely. It may have the disadvantage of inducing the student to lay too much stress upon his daily or occasional "performance," and of laboring with the instructor to give better "credits." It also removes from the better student the inducement to take a comprehensive view of the entire subject.

The object of examinations should be in harmony with the true objects of study. The latter are, at least, two-fold—to acquire knowledge and increase mental power. In accordance with this view, the better students may be benefited even more by an examination than the less fortunate. The true preparation, in this case, will be the securing of a good knowledge of the subject.

In my own practice I frequently grade the questions, giving to the stronger men questions which have not been discussed in the

lecture room, and which, if they fail to answer, will not prevent their "passing," but will furnish them material for thought in after days. Then other questions are fixed upon, requiring a minimum amount of knowledge allowable for "passing," and between these, questions of varying degrees of difficulty. During the past year I have tried a different system with the Senior class. I have given them original questions, intended to test their knowledge of the subject and their ability to apply its principles, and allowed the free use of the text book. It has worked well. The per cent. of failures has been comparatively large, but those "passed" have the satisfaction of knowing that they possess a sufficient command of the subject to enable them to apply it, and those "not passed" see for themselves that they have not acquired the knowledge they ought, and enter upon its study with renewed energy.

This method cannot be successfully used with all subjects—at least to the exclusion of every other method—for there are certain principles of every subject which should be firmly fixed in the memory, and the test for such knowledge should be made without resort to notes or to books. In many subjects an oral examination may profitably be combined with work upon original questions; the former to test, more particularly, memorized knowledge; the latter to test, more particularly, ability to use knowledge.

The student in passing over a subject for the first time should give careful attention to every detail; then upon review attention may be given to the more important, fundamental and leading principles; then an examination should test and fix them in one general view.

There are no fixed laws for examinations—and it is well there are none—for if there were the system would fall into a "rut," and this is one of the objections to the present English system. Independent thinkers avoid ruts, and they should also be avoided by students. System there should be—but one sufficiently flexible to be adapted to varying circumstances.

THE VAN VLECK DISCONNECTIVE ENGINE.*

THE latest addition to the series of large multi-cylinder engines is that built by the Dickson Mauufacturing Company, and designed by John Van Vleck, '84, chief electrician of the Edison Electric Illuminating Company. Mr. Van Vleck was assisted in his work by Mr. J. W. Sargent, and suggestions from Mr. David Joy and Mr. S. F. Prest are incorporated in the design.

The engine, which is for the Twenty-sixth Street station of the Edison Company, New York, has many distinctive features in common with the marine engine of the present. It has three cylinders with diameters of 18, 27 and 40 inches, and a common stroke of 30 inches. All the cylinders are double-acting, and attached to separate cranks at angles of 120 degrees. The rated speed is 130 revolutions, and it is designed to develop from 600 to 800 horse-power, running non-condensing, with an initial pressure of 150 pounds. The latest form of cast-steel conical marine piston-head is used, materially lightening the moving parts and reducing the length or height of the cylinders. The cross-heads are also of the marine type, with the regulation forked connecting rod. The guides are peculiar in that they have no side pieces, being plain flat surfaces, the forked end of connecting rod with its two bearings being largely depended upon to keep the alignment.

The crank-pins are 9 inches in diameter, 10 inches in length, and are between double disks. The main shaft is 9 inches diameter in the bearings, of which there are four; the longest being 20 inches in length and the shortest 13 inches. Upon the ends of the main shaft are carried the armatures of two 200-kilowatt Edison multipolar dynamos. These armatures are Gramme wound, the commutator forming part of the winding, Each weighs about five tons, and acts as a fly-wheel.

By means of valves in the steam pipes the engine may be run as compound, or in any desired combination, a reducing valve being used when the high-pressure cylinder is cut out. The valve gear is of the Joy type. A forked connection is attached to about the center of the connecting rod, the motion of the other end being

* Abstract of an article in *Power*, March, 1892.

constrained by a radius rod attached to the frame. From a point on this connection, a rod straddling both the connecting rod and the fork extends toward the front of the engine and terminates in a block, sliding between curved guides. From a point on this rod, just below the block, a rod extends to a small cross-head, which operates the valve stem. The curvature of the slipper guides, as they are called, is made upon a radius equal to the length of the rod to the valve stem cross-head, so that when the guides are in a position corresponding to an arc struck from the center of the valve cross-head pin the valve receives only a motion consequent upon the slight movement of the point to which its connecting rod is attached, sufficient only to move it through its lap and lead. When, however, the slipper guides are turned out of this position the block, in sliding between them, will be made to convey a movement to the valve, varying in amplitude with the displacement of the curved guides from the zero point. This displacing is accomplished by a hydraulic cylinder under control of the governor. The governor actuates a valve which admits or releases water from above and below a stationary plunger, whereby a small cylinder is moved up or down, which, being connected by links to cranks, turns a shaft running along the front of the engine to which are attached by other cranks and rods the ends of the slipper guides. The last-mentioned rods are adjustable in length, and upon their adjustment depends the relative distribution of the load between the cylinders. This feature also enables the point of cut-off on any cylinder to be varied at will when the engine is in motion. For every position of the slipper guide there is a corresponding point of cut-off for the valve, which is shown by an index, whose position is controlled by the governing mechanism.

The valves used are of the piston type, one each for the high pressure and intermediate cylinders, and two for the low pressure.

The outside dimensions of the engines, including dynamos, are 9 feet by 19 feet, giving but 171 square feet of floor space for the development of 600 to 900 horse-power and its conversion into electricity. An advantage is gained by placing the steam chests upon the sides of the cylinders, the length of the engine being thereby decreased some 40 per cent. from that required for an engine with the same dimensions and the chests between the cylinders. All the cylinders are fitted with removable liners; and the intermediate and low-pressure cylinders are jacketed, not

because the designer has any faith in the jacket as an aid to efficiency, but as a practical method of reducing trouble from moisture. The main guides and all the principal bearings are water jacketed. An engine of the same design and twice the capacity is now being constructed by the Dickson Company, for the new Elm Street station of the Edison Company, where it will form one of the set of small units, quadruple engines of the same design and as high as 5,000 horse-power being contemplated.

STEVENS INSTITUTE OF TECHNOLOGY.

A TRAINING SCHOOL FOR FUTURE RAILWAY MASTER MECHANICS.*

THE investment of the Boston fund in a scholarship in the Stevens Institute of Technology brings that institution into special relations with the members of the American Railway Master Mechanics' Association. It will probably not be long before in each of the four classes of the Institute a son of some master mechanic of an American railroad will be enrolled. And as the years pass, a steadily increasing number of those who have enjoyed the assistance and the distinction which this scholarship affords will be some of them, at the head of the mechanical departments of railways in various parts of the country, and others in positions of greater or less responsibility in these departments with the path of promotion and success opening before them. There are now several superintendents of motive power and master mechanics among the Alumni of Stevens Institute, and the Boston fund scholarship will surely result in an increased percentage of graduates who win such responsible and honorable positions. And it may well be added that to enter Stevens Institute of Technology under the Boston fund scholarship is a combination of advantage and honor well worth striving for.

If any railway master mechanic fears that his son, if he becomes a student at Stevens Institute, may receive too much "theoretical"

*Abstract of an article in the *Railway Master Mechanic*, March, 1892.

and too little "practical" education, a visit of two or three hours to the institution will dispel his fears. The spirit and atmosphere of the place is "practical" in the truest sense of the term. The class-rooms, the laboratories, and the shops are filled with evidences that the one great aim of those who have gradually and most carefully developed the system of instruction, and whose personality, character, and ability give the institution its tone and character, is to teach each student to apply the principles which he learns to the actual work of the world. The machine shop is a real shop, with machine tools, and is used regularly. In the carpenter shop, the pattern room, the molding floor and the foundry, genuine, careful work is going on, and the young men who are doing it are for the time being actual workmen, who put their brains and their muscle into their work without any fear of doing too much of it or doing it too well. As the visitor notes all these things and listens to the explanations and comments of the professor who accompanies him, he will cease to fear that his boy will become too much of a theorist if he sends him to this Institute. Theory and practice are not divorced here; they are inseparable and preside together over every recitation and every exercise.

The course of study in mechanical engineering, extending through four years, covers the entire field. The graduate will comprehend the general laws which regulate the action of forces, of the mechanism by which these forces are utilized, and of the materials of which such mechanism is constructed. He will know how work in the shop should be done, and, in a general way, will know how to do it. He will not only have mastered the principles of mechanical engineering as a science, but will have verified by actual work, the laws and rules and formulæ which make up that science.

It is not to be supposed for a moment that a graduate of this Institute will be competent to step from the graduating platform to the master mechanic's desk. Efficient and successful master mechanics cannot be made in that way, no matter how "practical" the institution in which they were educated. But the man who is a graduate of such a school, on entering that path of hard work which leads through many varied and severe experiences up to official position, responsibility and reward, will begin, so far as many kinds of valuable knowledge are concerned, where many old men leave off. He can pass through the early stages more rapidly than an uneducated man could do, and when he shows himself able

to handle men as well as tools, and so wins his promotion, he will (other things being equal) be worth more to the road than he would have been without his education.

The preliminary examinations which those who enter Stevens Institute must pass are rather severe, and it is not improbable that some who would have liked to compete last year for admission under the Boston fund scholarship decided not to do so for that reason. On this point it may be said that all first-class schools have so high a standard of admission that it is a proof of at least average ability to pass it. The number of candidates for admission to Stevens Institute each year is much in excess of the capacity of the institution. Until the buildings, apparatus and endowments of the Institute are increased, the number of students must be kept down to about what it now is. Steps are being taken to erect a large new building. There is, we believe no other fixed source of income for the general expenses of the institution than that provided by the founder of the Institute from his estate. It is believed, however, that some of the wealthy manufacturers and business men of the country will decide to give liberally to enlarge the capacity and power of an institution so excellently located, so firmly established, and of such high repute. But all this is in the future—not in the far future, we trust—and the only way to keep the number of students within a practicable limit, and yet give ability and industry a fair and equal chance for admission, is to insist upon strict and somewhat severe preliminary examinations. In the competition for entrance all have an equal chance, and if the victors are few in number, the honor to each is all the greater.

RULES AND TABLES USEFUL IN ENGINEERING PRACTICE.

IN the course of lectures delivered before the Senior class by Prof. Coleman Sellers, of the chair of Engineering Practice, a number of tables and formulæ, useful to to the engineer, were used in illustration of the kind of information that young engineers should collect for ready reference at any time. It is proposed to publish some of these from time to time.

The attention of the class was particularly called to the experiments that had been conducted with care by Mr. Wilfred Lewis for Wm. Sellers & Co., Inc., Philadelphia, in regard to the friction of screws, which were published in the *Journal of the Franklin Institute*, February, 1880.

From the more extended paper a graphical diagram, showing the power of screws, was prepared, which is given herewith, to which is appended the approximate formulæ for screws that have been used by Mr. Lewis; Prof. Sellers asserted that they had been relied upon in doing a great deal of important engineering construction with a decided improvement over the empirical methods that had been in use previous to this line of experimentation.

The purposes for which a screw is to be used, other than acting merely as a bolt to bind machinery together, is worthy of careful study, even with the possible great variation in the coefficient of friction under different conditions. An approximate knowledge of the friction enables an engineer to select such a pitch to the screw as either will stand without running down, or will run down with certainty when it is desirable that the action shall be of that character, the aim being to obtain from the screw the highest possible efficiency.

For the ready application, of the knowledge gained, to practice, Mr. Lewis had prepared for Prof. Sellers the formulæ now given, which is accompanied by the table of the proportion of gear wheels used in the same establishment.

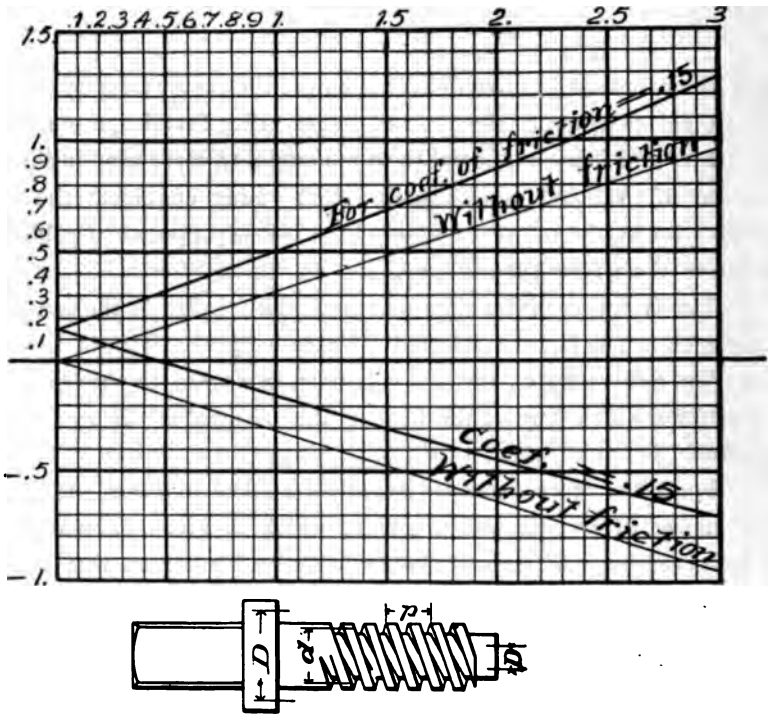

DIAGRAM SHOWING POWER OF SCREWS.

Abscissae = pitch of screw in terms of mean diameter = $\frac{p}{d}$.

Ordinates = tangential force in terms of weight raised or lowered, applied at mean diameter of screw.

When screw turns on step or collar, add $\frac{.15\ D}{d}$, in which D = mean diameter of step or collar.

When $p = \frac{1}{3}(D + d)$ a screw will sustain its load on a basis of .12 friction.

APPROXIMATE FORMULÆ FOR SCREWS.

The following formulæ may be applied with a close degree of accuracy to any bolt or nut turning upon a collar whose outside diameter is not more than twice or thereabouts that of the screw. No result can ever be taken as exact, because the co-efficient of friction is never constant, but for an average case in which the co-efficient may be assumed to be .15, the following formulæ are easily applied and quite near enough for practical purposes.

P = pitch of screw.

d = outside diameter of screw.

F = force applied at circumference to lift a unit of weight.

E = efficiency of screw.

Then $$F = \frac{P + d}{3\,d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

and $$E = \frac{P}{P + d} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

When a screw is intended to stand without running down, allowance must be made for a possible reduction in the co-efficient of friction, or when intended to certainly run down, allowance must be made for a possible increase in that co-efficient.

Letting D = mean diameter of collar.

Then the greatest pitch that will stand, or the least pitch that will not stand, may be expressed by the formula

$$p = 3\,\theta\,(d + D)\,P = 3\,\varphi\,(d + D) \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

in which θ = the co-efficient of friction.

For the greatest pitch that will stand θ should not be assumed greater than .10 or .12, and

For the greatest pitch that will not stand, assume θ not less than .20, but these values are matters of judgment depending on circumstances and conditions.

The following table gives the proportions of gear wheels recommended by Professor Sellers in his lecture on "The Drawing Room."

PROPORTIONS OF GEAR WHEELS.

Per Inch.	Pitch.	Outside of Pitch Line. $P_x.3$.	Inside of Pitch Line.		Width of Space.	
			For Cast or Cut Bevels or for Cast Spurs. $P_x.4$.	For Cut Spurs. $P_x.35$.	For Cast Spurs or Bevels. $P_x.525$.	For Cut Bevels or Spurs. $P_x.51$.
	¼	.075	.100	.0875	.13125	.1275
12	.2618	.07854	.10472	.091630	.137445	1.133518
10	.31416	.094248	.125664	.1099560	.164934	.1602216
	⅜	.1125	.1500	.13125	.196875	.19125
8	.3927	.11781	15708	.137445	.2061675	.200277
7	.4477	.13431	.17908	.156695	.2350425	.228327
	½	.15	.20	.175	.2625	.255
6	.5236	.15708	.20944	.183260	.27489	.267036
	9/16	.16875	.225	.196875	.2953125	.286875
	⅝	.1875	.25	.21875	.328125	.31875
5	.62832	.188496	.251238	.219912	.329868	.3204432
	¾	.225	.3	.2625	.39375	.3825
4	.7854	.23562	.31416	.274890	.4123350	.400554
	⅞	.2625	.35	.30625	.459375	.44625
	1	.3	.4	.35	.525	.51
3	1.0472	.31416	.41888	.36652	.54978	.534072
	1⅛	.3375	.45	.39375	.590625	.57375
2¾	1.1424	.34272	.45696	.399840	.59976	.582624
	1¼	.375	.5	.4375	.65625	.6375
2½	1.25664	.376992	.502656	.439824	.659736	.6408864
	1⅜	.4125	.55	.48125	.721875	.70125
	1½	.45	.6	.525	.7875	.765
2	1.5708	.47124	.62832	.54978	.82467	.801108
	1¾	.525	.7	6125	.91875	.8925
	2	.6	.8	.7	1.05	1.02
1½	2.0944	.62832	.83776	.73304	1.09956	1.068144
	2¼	.675	.9	.7875	1.18125	1.1475
	2½	.75	1.00	.875	1.3125	1.275
	2¾	.825	1.100	.9625	1.44375	1.4025
	3	.9	1.2	1.05	1.575	1.53
1	3.1416	.94248	1.25664	1.09956	1.64934	1.602216
	3¼	.975	1.3	1.1375	1.70625	1.6575
	3½	1.05	1.4	1.225	1.8375	1.785

Thickness of Rim below Root — Depth of Tooth.

STRENGTH OF SPUR GEARING.

The following table has been determined graphically for the standard system of interchangeable cycloidal teeth, and the factors given stand for the load applied at the end of a tooth 1 inch pitch and 1 inch face, to produce a stress of 10,000 pounds per square inch at the weakest point. To find the strength of a given wheel, therefore, a factor, corresponding to the proper number of teeth, must be multiplied by the pitch and face of the wheel in inches.

For any desired working strength, as recommended for cast iron and steel in the subjoined table, multiply again by the value there given, and point off four decimal places:

Number of Teeth.	Factor at 10,000 Pounds Per Sqare Inch.	Number of Teeth.	Factor at 10,000 Pounds Per Square Inch.
10	610	25	970
11	640	27	1,000
12	670	30	1,020
13	700	34	1,040
14	720	38	1,070
15	750	43	1,100
16	770	50	1,120
17	800	60	1,140
18	830	75	1,160
19	870	100	1,180
20	900	150	1,200
21	920	300	1,220
23	940	Rack	1,240

SAFE WORKING STRENGTH FOR DIFFERENT SPEEDS.

Speed of Gear Teeth in Feet Per Minute.	Cast Iron.	Steel.	Speed Per Minute.	Cast Iron.	Steel.
100 or less	8,000	20,000	900	3,000	7,500
200	6,000	15,000	1,200*	2,400	6,000
300	4,800	12,000	1,800	2,000	5,000
600 .	4,000	10,000	2,400	1,700	4,300

*To avoid great noise, do not run over 1,200 feet.

These values have been deduced from an English rule, but no demonstration of their correctness has, as yet, been made.

TABLE SHOWING THE STRENGTH OF GEARING AT PITCH LINE, AND AT END OF TOOTH AS DETERMINED GRAPHICALLY.

The factors here given are for the breaking strength of cast iron estimated at 17,000 pounds per square inch, and are to be multiplied by the pitch and face of any given tooth.

Number of Teeth.	Pitch Line.	End of Tooth.	Number of Teeth.	Pitch Line.	End of Tooth.	Number of Teeth.	Pitch Line.	End of Tooth.
10	1,620	1,040	25	2,520	1,650	Internal	Teeth	Wheels
11	1,650	1,090	27	2,620	1,700	300	4,000	2,130
12	1,720	1,140	30	2,720	1,730	150	4,100	2,160
13	1,790	1,190	34	2,860	1,770	100	4,230	2,190
14	1,840	1,220	38	2,920	1,820	75	4,370	2,230
15	1,900	1,280	43	3,040	1,870	60	4,490	2,240
16	1,990	1,360	50	3,150	1,900	50	4,620	2,250
17	2,040	1,360	60	3,260	1,940	43	4,760	2,260
18	2,110	1,410	75	3,370	1,970	38	4,900	2,280
19	2,190	1,480	100	3,490	2,010	34	5,010	2,300
20	2,260	1,530	150	3,600	2,040	30	5,170	2,310
21	2,350	1,560	300	3,740	2,070	.....	.....	.....
23	2,430	1,600	Rack	3,860	2,110	....	. ...	.....

We also publish the speed of cut for lathes and planers.

SPEED OF CUT FOR LATHES AND PLANERS.

Brass may be turned at high speeds like wood.

Bronze.—A speed of 18 feet per minute can be used with the soft alloys, say 8 to 1, while for hard mixtures a slow speed is required, say 6 feet per minute.

Wrought Iron can be turned at 40 feet per minute, but planing machines that are used for both cast and forged iron are operated at 18 feet per minute.

Machinery Steel, Class III., 14 feet per minute. Class II., car axles, etc., 9 feet per minute.

Wheel Tires, Class IV. and V., at 6 feet per minute; the tool stands well, but many prefer to run faster, say 8 to 10 feet, and grind the tool more frequently. The rules of Calculus can be applied to the question of economy of speed, measured by the durability of the tool.

Lathes.—The speeds obtainable by means of the cone pulley and the back gearing is in geometrical progression from the slowest

to the fastest. In a well proportioned machine the speeds hold the same relation through all the stops. Many lathes have the same speed on the slowest of the cone and the fastest of the back gear speeds. I advise the examination of the lathes in the shop of the Stevens Institute and a careful examination of the speeds, also the planning of other combinations of speed, to fully understand the subject of the relative speeds.

Speed of Counter-Shaft of the lathes is determined by an assumption of a slow speed with the back gear, say 6 feet per minute, on the largest diameter that the lathe will swing.

Example.—A 30-inch lathe will swing 30 inches = say, 90 inches circumference = 7′ 6″; the slowest tripple gear should give a speed of 5 or 6 feet per minute.

Professor Sellers has furnished the list of gas pipes, the taper of thread three-fourths of an inch per foot, which has been found of service to himself in selecting the pipe suitable to any required pressure in hydraulic work or in steam fitting.

LIST OF GAS PIPES.

Taper of thread, ¾ inch per foot.

Size of Pipe.	Outside Diameter.	Inside Diameter.	Inches Diameter. Extra Strong	Inches Diameter. Double Extra Strong.	Threads per Inch.
⅛″	.405	.27	.205	.....	27
¼″	.54	.364	.294	.....	18
⅜″	.675	.494	.421	.....	18
½″	.84	.623	.542	.244	14
¾″	1.05	.824	.736	.422	14
1″	1.315	1.048	.915	.587	11½
1¼″	1.66	1.38	1.272	.884	11½
1½″	1.9	1.611	1.494	1.088	11½
2″	2.375	2.067	1.933	1.491	11½
2½″	2.875	2.468	2.315	1.755	8
3″	3.5	3.067	2.892	2.284	8
3½″	4.	3.548	3.358	2.716	8
4″	4.5	4.026	3.818	3.136	8
4½″	5.	4.508	.....	.....	8
5″	5.563	5.045	.....	.....	8
6″	6.625	6.065	.....	.....	8
7″	7.625	7.023	.....	.....	8
8″	8.625	7.982	.....	.....	8
9″	9.688	9.001	.....	.....	8
10″	10.75	10.019	.....	.....	8

The size of keys, both for shafting and for machine tools, are the proportions adopted by William Sellers & Co., and rigidly adhered to during a period of nearly forty years. Their practice in making keys and fitting them is, that the key shall always bind tight sidewise but not top and bottom; that is, not necessarily touch either at the bottom of the key seat in the shaft or touch the top of the slot cut in the gear wheel that is fastened to the shaft, but in practice, keys used in this matter depend upon the fit of the wheel upon the shaft being a forcing fit, or a fit that is so tight as to require screw pressure to put the wheel in place upon the shaft.

In this connection it may be well to observe that Professor Sellers advocates a system, largely used in the same establishment, of splitting the hubs of pulleys without splitting the rim, and arranging bolts to draw the split hub together, so as to present, when screwed up, the conditions of a forcing fit. In such case the hole in the pulley is bored of the size it would be for a forcing fit, and the split hub is wedged open to allow it to be pushed upon the shaft readily, and the wedges being knocked out, the bolts draw the halves tightly together. This practice with pulleys, both for line shafting and the machine tools, has been found to work admirably and be quite economical in the cost of construction.

SIZE OF KEYS FOR SHAFTING.

Diameter of Shaft.	Size of Key.
$1\frac{1}{4}$ " — $1\frac{7}{16}$" — $1\frac{1}{2}$"	$\frac{5}{16}$" x $\frac{3}{8}$"
$1\frac{5}{8}$" — $2\frac{3}{16}$" —	$\frac{7}{16}$" x $\frac{1}{2}$"
$2\frac{7}{16}$" —	$\frac{9}{16}$" x $\frac{5}{8}$"
$2\frac{1}{16}$" — $2\frac{5}{16}$" — $3\frac{3}{16}$" — $3\frac{7}{16}$"	$\frac{11}{16}$" x $\frac{3}{4}$"
$3\frac{5}{16}$" — $4\frac{7}{16}$" — $4\frac{15}{16}$" —	$\frac{13}{16}$" x $\frac{7}{8}$"
$5\frac{7}{16}$" — $5\frac{15}{16}$" — $6\frac{7}{16}$" —	$\frac{15}{16}$" x 1"
$6\frac{1}{16}$" — $7\frac{7}{16}$" — $7\frac{15}{16}$" — $8\frac{7}{16}$" — $8\frac{15}{16}$"	$1\frac{1}{16}$" x $1\frac{1}{8}$"

Length of keyseat for coupling — $1\frac{1}{8}$ × nominal diameter of shaft.

The following table, introduced in the lecture on designing, gives the size of keys for machine tools for various diameters of shaft:

SIZE OF KEYS FOR MACHINE TOOLS.

Diameter of Shaft.	Size of Key.
$\frac{11}{16}$ inches and under.	$\frac{1}{8}$ inches by $\frac{1}{8}$ inches.
1 " " $1\frac{5}{16}$ inches.	$\frac{5}{16}$ " by $\frac{5}{16}$ "
$1\frac{1}{4}$ " " $1\frac{7}{16}$ "	$\frac{1}{4}$ " by $\frac{1}{4}$ "
$1\frac{1}{2}$ " " $1\frac{11}{16}$ "	$\frac{5}{16}$ " by $\frac{5}{16}$ "
$1\frac{3}{4}$ " " $2\frac{5}{16}$ "	$\frac{7}{16}$ " by $\frac{7}{16}$ "
$2\frac{1}{4}$ " " $2\frac{11}{16}$ "	$\frac{9}{16}$ " by $\frac{9}{16}$ "
$2\frac{3}{4}$ " " $3\frac{13}{16}$ "	$\frac{11}{16}$ " by $\frac{11}{16}$ "
4 " " $5\frac{7}{16}$ "	$\frac{13}{16}$ " by $\frac{13}{16}$ "
$5\frac{1}{2}$ " " $6\frac{15}{16}$ "	$\frac{15}{16}$ " by $\frac{15}{16}$ "
7 " " $8\frac{15}{16}$ "	$1\frac{1}{16}$ " by $1\frac{1}{16}$ "
9 " " $10\frac{15}{16}$ "	$1\frac{3}{16}$ " by $1\frac{3}{16}$ "
11 " " $12\frac{15}{16}$ "	$1\frac{5}{16}$ " by $1\frac{5}{16}$ "
13 " " $14\frac{15}{16}$ "	$1\frac{7}{16}$ " by $1\frac{7}{16}$ "

The following method was used by Professor Sellers while at William Sellers & Co.'s, to get the proportions of the parts of machines, based upon the size obtained in building a large machine and a small one to any series of machines. This formula is used in getting up the proportion book and arranging the set of proportions from which any machine can be constructed of intermediate size between the largest and smallest of the series.

RULE TO ESTABLISH CONSTRUCTION FORMULÆ.

Take difference between the nominal sizes of the largest and the smallest machines that have been designed of the same construction. Take also the difference between the sizes of similar

parts on the largest and smallest machines selected. Divide the latter by the former, and the result obtained will be a "*factor*," which, multiplied by the nominal capacity of the intermediate machine, and increased or diminished by a constant "increment" will give the size of the part required. To find the "increment": Multiply the nominal capacity of some known size by the factor obtained, and subtract the result from the size of the part belonging to the machine of nominal capacity selected.

Example.—Suppose the size of a part of a 72-inch machine is 3 inches, and the corresponding part of a 42-inch machine is $1\frac{7}{8}$, or 1.875 inches; then $72 - 42 = 30$, and 3 inches $- 1\frac{7}{8}$ inches $= 1\frac{1}{8}$ inches $= 1.125$. $1.125 \div 30 = .0375$ = the "factor," and $.0375 \times 42 = 1.575$. Then $1.875 - 1.575 = .3$ = the "increment" to be added. Let D = nominal capacity; then the formula will read: $x = D\text{x } .0375 + .3$.

Proof: $42 \times .0375 + .3 = 1.875$, or $1\frac{7}{8}$, the size of one of the selected parts.

Some prefer the formula: $aD + c = x$, in which D = nominal capacity in inches or in pounds, c is a constant increment, a is the factor, and x = the part to be found.

$$a\ 36 + c = 4 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$
$$a\ 12 + c = 2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Subtracting (2) from (1) $\ldots . a\ 24 \quad = 2$;

then $a = \frac{2}{24} = \frac{1}{12}$; and by substitution we get $\frac{1}{12}^{2} + c = 2$, and $c = 2 - \frac{1}{12}^{2} = \frac{1}{12}^{2} = 1$. The formula will then be:

$$\frac{1}{12}D + \frac{1}{12}^{2} = \frac{D + 12}{12} = x$$

THE MID-WINTER MEETING OF THE ALUMNI ASSOCIATION.

THE winter meeting of the Stevens Institute Alumni Association, which was held in the lecture-room of the Stevens School on Monday evening, February 15th, was late in beginning, but when President Edward B. Wall, '76, rapped for order, nearly every seat was filled by members of the Faculty and graduates of the Institute.

The reading of the minutes of the previous meeting was dispensed with, as they had already been published in the INDICATOR, and the important business of the evening was begun without delay.

President Wall made the following address:

Gentlemen of the Faculty, Members of the Alumni Association: We belong to the youngest profession in the world. It is our task to battle directly with Nature. The others, the theologians, the jurists, the economists, all deal with the relations of man to man. They are concerned with the development of civilization, and it is only by civilization that we are rated the youngest of the professions. Yet when we remember that in the pursuit of our labors we go back to that most elemental condition of mankind, where the battle was for food and shelter; where man had to support life before he could take up his relations with his fellow man, we can say with truth that we belong to the oldest profession in the world.

The work of the engineer is to wrest from Nature those secrets that she doles out so grudgingly at such infinite cost of brain and health and life. In his education, that is, the education you gentlemen give here, he does not follow the well-worn paths of learning, but at the start he buys his text-book and his overalls together, takes his place at the work bench, and with hammer and chisel in hand, he opens the battle; and usually he is little more than a boy like those others, the students of other professions, who have not yet touched realities. At the outset our lives are very real. We are launched into man's work before we are men. That it is a test, no one doubts, and the question as to what manner of man this tremendously practical education produces can best be answered by

the demand from nearly all parts of the world for the kind of training that the Faculty of Stevens has given us.

This institution has now attained its 21st year. We have reached our majority. We have had our share of this splendid inheritance. The Faculty has done its part; they have filled the college to overflowing, until it is now suffering from a temporary congestion. Now it is for us to do our part. Let us come forward, and with our help, our interests, and our money make possible the enlargement of Stevens' sphere of action.

Gentlemen of the Trustees and of the Faculty, by way of showing that we desire to enter into a contract to further the interests of the Institute, by way of earnest money, as the lawyers say, we wish now to present to the Institute the portrait of the honored President, the man who has devoted to Stevens his ability, his energy, his time, his tact, and his private fortune, DR. HENRY MORTON.

He then unveiled a full-length portrait of President Henry Morton, of which our frontispiece is a reproduction.

At the particular request of President Morton the original is in black and white, painted by Mr. A. D. Turner, of New York. It is half life size, the entire picture being 50 inches high and 34 inches wide.

This reproduction, made by the "Ives" process, will enable all to judge of the likeness and artistic merits of the picture, though something of its impressive effect is lost by the great reduction in size.

The original well deserves to be called a "speaking likeness," for, when one first looks at it, the impression is of a solid figure, ready to step out of the frame, and in the very act of uttering something with the vivacity characteristic of its subject.

The surroundings of the figure are highly appropriate.

The scene is a corner of the familiar lecture-room, where the President stands by the blackboard, whereon he has just drawn a diagram about which he is in the act of speaking.

The spectroscope on the table at his side is the one with which he made a series of researches on Fluorescent Spectra, which have been published in the principal scientific journals of this country and Europe.

This work was done at the window behind him, which, facing south, made it convenient to introduce direct sunlight by means of a "portelumiere."

Close to the spectroscope is the end of the induction coil, which was made for President Morton 20 years ago, and was then, and is now, substantially, the most powerful apparatus of its kind in existence.

On the floor below stands the "College Lantern," which President Morton did so much to develop, and which he applied so successfully in his early lectures before large audiences.

At the right of the picture, against the apparatus case, hangs one of the very large Geissler tubes, which he caused to be constructed for use with the large induction coil, and in front of it stands a modification of Gassiot's "Electric Star," which figured conspicuously at some of the Academy of Music lectures, referred to in Dr. Coleman Sellers' address.

When the applause which followed the unveiling had subsided Professor Coleman Sellers, in behalf of the Faculty, accepted the picture and spoke of the career of the President, whom he had known for more than thirty years. [Dr. Sellers' address is the first article in this number.]

Alexander C. Humphreys, '81, the leading member of the President Morton Portrait Committee, reported substantially as follows:

In response to circulars sent out by the Special Committee and the Alumni Association Executive Committee, subscriptions have been received that will be more than sufficient for the purpose.

After having arranged the details and sent out the circulars, the committee found that President Morton was very reluctant to encourage the spending of as large an amount of money as the committee first thought would be required to procure such a portrait as would fittingly preserve the likeness of our respected President.

The committee, however, through the co-operation of Dr. Morton was able to make such an arrangement as, it is hoped, will be satisfactory to all, both as to the value of the portrait as a likeness and as to the expenditure involved.

The committee, being anxious that full advantage should be taken of this pleasant opportunity, is arranging to distribute to the subscribers a souvenir of this occasion in the form of a brief memoir of President Morton, accompanied by a reproduction of the portrait. This will be published and distributed as promptly as possible, and, it is hoped, will be a fitting reminder of this meeting, which promises to be such an important one to Stevens and its Alumni.

While a final report cannot be made at this time, it is well to state that subscriptions to this fund, to the amount of $980.50, have been received from 190 persons, the subscriptions, therefore, averaging a little over $5 each. Alumni in foreign parts are still sending in their subscriptions.

After paying for the portrait and the souvenir a balance of about $500 will remain in the treasurer's hands, and the committee recommends that Dr. Morton be requested to appropriate this surplus to some special Stevens work.

The committee wishes to return its thanks for the hearty way in which its scheme has been endorsed by the subscribers.

It may be a pleasure to President Morton to know that the letters received from the subscribers show clearly how generally are appreciated by the Alumni and all others connected with the Institute his conscientious, wise and earnest labors in behalf of Stevens.

ALFRED R. WOLFF.
WM. HEWITT.
GEO. M. BOND.
ALEX. C. HUMPHREYS.

The Secretary, J. M. Rusby, '85, stated that the new Board of Trustees would consist of twelve members, three of whom were to be chosen by the Alumni Association. There being already one Alumni Trustee, this arrangement makes vacancies for two more graduates on the Board, which will be filled next June.

Then came what was in many ways the most interesting part of the meeting, an earnest discussion of the means of raising the money for the proposed new building. The Corresponding Secretary, William L. Lyall, '84, brought the subject before the house by giving an outline of the work of the Executive Committee as far as they had gone. Circulars had been sent to the Alumni and $3,500

had already been subscribed by only 28 men. A little later in the evening Frank E. Idell, '77, the Vice-President of the Association, said that the original idea had been to ask the graduates to pay 5 per cent. interest on $50,000 worth of bonds for ten years, but this plan was discarded, as, after raising $25,000 interest, they might still be called upon to subscribe the principal. The committee had now resolved to ask for the principal outright, and from the cheering responses it had received thus far, there seemed to be no doubt that the necessary sum could and would be raised.

President Morton spoke of the necessity for more room. At the last entrance examination 30 desirable men had been refused admittance, because there was really no place to put them in. The Institute had been originally designed to accommodate 100 students, and as there are now 220, it can be readily imagined that there must be crowding somewhere. He was sure that if the Alumni showed that they were thoroughly in earnest in the matter there would be no great difficulty in raising the money, for help would come from outside when it was seen how pressing the need for better accommodations was. He himself had been accumulating a fund of $20,000 for the endowment of a Chair of Engineering Practice, and as it was not necessary to devote it to that purpose yet, the income from it could be used for the building. He intimated that when the proper time arrived a metallurgical laboratory might be erected, in addition to the other buildings.

Gus C. Henning, '76, suggested the propriety of having a large testing laboratory with a complete plant which could be made self-sustaining and would be a commercially profitable investment. At present there is nothing of the kind in this country and one is much needed.

Professor Sellers compared our American schools of mechanical engineering with those of the Old World, pronouncing the former superior in many ways. Dr. Leeds suggested that manufacturing chemists, being a class of manufacturers who might profitably employ the graduates of such an institution as Stevens, could

probably be interested in our project, if approached. Professor Mayer made some remarks, both amusing and serious, which were thoroughly enjoyed by the whole assembly.

Mr. Kursheedt proposed the incorporation of the Alumni Association and the issuing of bonds for the purpose of raising money for the new building.

Professor Wood then arose and said that he had been listening to everybody else's plans, and that he now had a scheme of his own to propose. There are at present over 120 scholars in the Senior Class of the Stevens School, most of whom are anxious to enter the Institute next fall. What is to be done with them? He would admit at least 100, divide the class into sections, and have some of the men do shop-work in the morning and recite in the afternoon. In this way things could be managed during the Freshman year, but what would happen when they became Sophomores? The present laboratory would not hold them. This difficulty could be overcome by issuing bonds, beginning the new building at once, so that it would be ready by the fall of '93, and then paying the interest on the bonds by raising the tuition fees $10 for each man, which would not be at all unfair, when the great advantages which Stevens students enjoy are considered.

There were more remarks made by E. D. Self, '86, Philip E. Raque, '76, and many others, and finally Mr. Idell, in answer to some questions, and in order to satisfy some doubts, gave a concise account of what the Executive Committee proposed to do and how they intended doing it.

The new building is to have Professor Mayer and the physical department on the top floor. Two floors will be devoted to chemistry, with enough space reserved on them for the Department of Languages. What shall be done with the basement has not been fully determined, though there will be no difficulty in finding something to fill it with. Then in the main building the Drawing Department can take possession of Professor Kroeh's room, Professor Denton can use the physical laboratory, "and have a little spiral

stairway leading down below" to his apartment in the east basement, and all the overcrowding will be done away with until we have several hundred more students. "It will take some money to make this improvement, and this is just where the Alumni are asked to step up and show their love for their *alma mater*." Outside help will be forthcoming when the graduates show a disposition to do all in their power. The trustees have already agreed to fit up the interior of the new building and furnish it, as soon as it is erected.

Samuel D. Graydon, '75, offered resolutions endorsing the action of the Executive Committee, assuring them of the Association's hearty support, and pledging every member present to do his utmost to further the good cause. These resolutions were unanimously adopted and are embodied in the accompanying circular of the Executive Committee of the Alumni Association.

Secretary Lyall read a list of the subscribers, and many names were added to it before the evening was over, swelling the total amount to upward of $10,000.

A motion was unanimously carried, thanking the trustees for allowing the Alumni increased representation on the Board, and then Professor Bristol reported for the "Collation Committee," and the Association went into executive session in the adjoining room and thoroughly discussed the last named committee's report, which was spread before them.

Altogether the meeting was a most interesting and enthusiastic one, from which we may reasonably expect that much good will come. If all the friends of Stevens do their duty, good must come.

THE PROPOSED NEW BUILDING.

IN carrying out the resolution of Mr. Graydon at the Alumni meeting, the Executive Committee issued on March 22d the following circular:

NEW YORK, MARCH 28TH, 1892.

To the Alumni of Stevens Institute:

The following letter from President Morton received by the Executive Committee in reply to a request for the information contained, furnishes, the committee feel, a better statement of the Institute needs than any they could make and answers fully the questions which will naturally arise in the mind of every alumnus.

STEVENS INSTITUTE OF TECH.,
HOBOKEN, N. J., March 22, 1892.

The Alumni Association Executive Committee:

GENTLEMEN: In reply to your request for information I would say that your impression as to the need of room in the Institute building to accommodate the applicants for admission who present themselves, is entirely correct. This condition has existed for several years, and has been steadily increasing.

The desire of the Faculty and Trustees not to refuse the benefits of our course to worthy applicants, has led us to strain every mode of accommodation to its utmost limit, and the position now is such that not only is it physically impossible for us to accommodate the increased numbers certain to apply next season, but we are prevented from making numerous improvements in various departments, which are most desirable, in order that we should hold our leading position among technical schools—for lack of space within our present buildings.

We are, in fact, in the position of a manufacturing concern whose business has outgrown its "plant."

With a manufacturing establishment the remedy would be simple, because the increase in business would warrant an increase

in capital investment, which, under such circumstances, could be readily secured by the usual financial methods.

But with an educational institution the case is different. No such institution for the higher education has in the history of the world been a source of financial profit. On the contrary, all such institutions the world over have required large endowments or equivalent Government support.

We may well feel proud when we compare what we are doing with only a modest endowment as measured by the funds at the command of other institutions; but there is limit to what the best of management can accomplish with limited means, and it is hardly necessary to say that our Trustees would not be authorized to diminish our small endowment fund by taking from it the amount necessary to erect additional buildings, the filling and maintenance of which are not unlikely to constitute a further draft on our resources.

We must then look to the liberality of our friends (among whom none, I am happy to say, are more sincere than our Alumni) to carry on and supplement the good work of our founder, by supplying us with at least the additional buildings needed to carry on our work with increasing efficiency, and thus to maintain our pre-eminent position, as well as to extend our range of usefulness.

What it is proposed to do, if the means can be provided, is to erect an additional building, at a cost of $50,000, which shall accommodate the departments of Chemistry, Physics, and Languages, and thus give us space in our present building for the much needed extension in our departments of Drawing, Mathematics, Engineering and Applied Mechanics.

Plans for the new building are in course of preparation, and it is hoped that they will be in concrete and presentable shape at the time of the June meeting of the Alumni.

The interest already exhibited by the Alumni in this matter has been most gratifying, and I do not doubt that their good example will be followed on all sides. For myself I can only say that what I do towards this work will be only limited by my ability, and I am sure that many others have the same inclination.

With sincere regards and the liveliest confidence in the success of our united efforts, I remain,

Sincerely yours,

HENRY MORTON.

The Executive Committee are happy to announce that the plans for erecting a new building at Stevens are meeting with the hearty support and endorsement of the Alumni; that generous subscriptions, amounting to some $12,605, from some fifty-seven subscribers, have already been pledged, and that at the recent winter Alumni meeting the following resolutions were passed unanimously:

Whereas, We recognize the importance to the Institute of promptly securing the proposed building, and rejoicing in the generous pledges already obtained, we heartily endorse the plan suggested by the Executive Committee;

Resolved, That the Executive Committee be and they are hereby given full power to do all lawful and necessary acts in furtherance of their plans, including the appointment of one member of each class to co-operate with the Committee in securing subscriptions and collecting contributions to the fund, which shall be known as the Alumni Building Fund.

All collections shall be promptly turned over, or subscriptions paid directly to Professor A. Riesenberger, Acting Treasurer of Stevens Institute, who shall receipt therefor, deposit all sums received in bank, and hold all such deposits subject to the order of the Executive Committee.

Resolved, That in view of the arduous task hereby imposed upon the Executive committee, we hereby individually pledge our earnest efforts to promptly raise the $50,000 required.

Resolved, That a copy of these resolutions, together with a list of the members present, and a list of the members appointed from the various classes by the committee, be mailed to each member not in attendance.

It is proposed to raise the required fund by the following modes of subscription:

Form 1.—By subscriptions payable sixty days after they are called for by the Executive Committee.

Form 2.—By subscriptions in such annual payments as the subscriber may indicate, the final payment, however, to be made within three years.

Inasmuch as it is believed that the sum sought is too large to be raised solely by contributions from the Alumni, and that friends must be relied upon to aid, we urge members to exert themselves to interview friends, associations, and others who are in a position to assist.

Subscriptions of this character, amounting to $1,700, have already been pledged—three of $500 each, conditionally on two more for like amount being obtained—and $200 unconditionally.

Members sending in such subscriptions should append thereto their names and addresses for purpose of identification.

The Executive Committee are authorized to announce that each contributor to the amount of $5,000 will be entitled to a perpetual scholarship, enabling him or his heirs to appoint the students to fill the same, who shall be entitled to free tuition, subject, of course, to the Institute regulations.

In accordance with the aforesaid resolutions, the following Alumni have been appointed to co-operate with the Executive Committee in securing subscriptions:

J. Augustus Henderson, '73, Lemont, Pa.
Wm. Hewitt, '74, Trenton Iron Co., Trenton, N. J.
S. D. Graydon, '75, 41 Dey Street, New York.
A. R. Wolff, '76, 38 Park Row, New York.
F. E. Idell, '77, 41 Dey Street, New York.
H. T. Brück, '78, C. & P. R. R., Mt. Savage, Md.
Maunsel White, '79, Bethlehem Iron Co., Bethlehem, Pa.
W. P. Parsons, '80, Trenton Iron Co., Trenton, N. J.
H. C. White, '81, Phœnix Iron Works, 15 Cortlandt Street, New York.
Jos. Wetzler, '82, 150 Broadway, New York.
Ernest N. Wright, '83, "Hazlebrook," Germantown, Pa.
H. F. Mitchell, '84, College City of N. Y., 17 Lexington Ave., New York.
Wm. A. Adriance, '85, Adriance, Platt & Co., Poughkeepsie, N. Y.
C. J. Field. '86, 143 Liberty Street, New York.
J. Day Flack, '87, Edison General Electric Co., Harrison, N. J.
Geo. Dinkle, Jr., '88, 165 Washington Street, Jersey City, N. J.
David H. Gildersleeve, '89, Hotel Broezel, Buffalo, N. Y.
E. H. Whitlock, '90, Brookings, South Dakota.
J. Arnold Norcross, '91, Cons. Gas. Co., 99th Street and 2d Ave., New York.

The co-operation of the Presidents of the several classes now at the Institute has also been requested in securing subscriptions from the undergraduates, the committee feeling that our future Alumni should also be allowed the privilege of contributing.

It is the earnest desire of the Executive Committee that every alumnus and undergraduate (our future Alumni) shall share in this

undertaking, and no matter how small the subscription it will be heartily welcome.

THE EXECUTIVE COMMITTEE,

EDWD. B. WALL, *President.*
WILLIAM L. LYALL, *Cor. Sec'y.*
540 West Twenty-Third Street, New York.

The following are the subscriptions already received:

President Henry Morton gives the interest on $20,000 of bonds, until the building is paid for, which for three years will amount to about	$3,000
The bonds to be given eventually towards the endowment of the Chair of Engineering Practice.	
Prof. A. R. Leeds	500
Prof. A. M. Mayer	300
Prof. Coleman Sellers	100
From the Alumni (49 subscribers)	7,005
From friends:	
Pledged by A. C. Humphreys, '81, conditionally	500
Pledged by S. D. Graydon, '75, conditionally	500
Pledged by George Dinkle, Jr., '88, conditionally	500
Pledged by E. B. Renwick, '84, unconditionally	200
Making total of	$12,605

List of those in attendance at the Winter Alumni Meeting.

President Henry Morton.
Prof. Coleman Sellers.
" A. M. Mayer.
" De Volson Wood.
" C. W. MacCord.
" A. R. Leeds.
" C. F. Kroeh.
" Edwd. Wall.
" J. E. Denton, '75.
" W. E. Geyer, '77.
" T. B. Stillman, '83.
Ass't Prof. A. Riesenberger, '76.
" Wm. H. Bristol, '84.
" D. S. Jacobus, '84.
Wm. Hewitt, '74.
S. D. Graydon, '75.
I. N. Knapp, '75.
G. C. Henning, '76.
P. E. Raque, '76.
H. K. Morrison, '86.
Edw. D. Self, '86.
R. M. Anderson, '87.
J. Calisch, '87.
J. H. Cuntz, '87.
Walter S. Dix, '87.
B. F. Hart, Jr., '87.
W. E. Parsons, '87.
A. H. Schlesinger, '87.
Richd. Beyer, '88.
H. A. Bang, '88.
Geo. Dinkle, Jr., '88.
Edwd. Ducommun, '88.
B. P. Hall, '88.
F. Uhlenhaut, Jr., '88.
J. Wolff, '88.
Henry L. Ebsen, '89.
James Eastwood, '89.
H. J. Gubelman, '89.

A. P. Trautwein, '76.
A. R. Wolff, '76.
Edwd. B. Wall, '76.
A. G. Brinckerhoff, '77.
F. E. Idell, '77.
E. P. Roberts, '77.
H. T. Brück, '78.
J. R. Stephens, '78.
W. W. Dashiell, '79.
Geo. M. Bond, '80.
R. S. Kursheedt, '80.
A. C. Humphreys, '81.
Jos. Wetzler, '82.
H. A. Hickok, '83.
E. H. Foster, '84.
W. L. Lyall, '84.
E. B. Renwick, '84.
Edwd. Burhorn, '85.
A. G. Glasgow, '85.
J. M. Rusby, '85.
W. W. Renwick, '85.
W. S. Chester, '86.
D. H. Gildersleeve, '89.
W. M. Hill, '89.
N. H. Hiller, '89.
E. M. Rosenberg, '89.
John S. De Hart, Jr., '90.
Chas. J. Everett, Jr., '90.
Wm. A. Ebsen, '90.
E. E. Hinkle, '90.
W. F. Lawrence, '90.
A. B. Moore, '90.
E. H. Peabody, '90.
S. F. Smith, '90
Benj. W. Carll, '91.
John Darby, '91.
F. B. De Gress, '91.
John M. Hansen, '91.
A. B. Mount, '91.
G. L. Manning, '91.
L. H. Nettleton, '91.
J. A. Norcross, '91.
F. N. Sanborn, '91.
H. W. Smith, '91.

On the 3d and 4th of April notices of the action of the Alumni and the circular of the Committee appeared in a number of the New York daily papers, including the *Times*, *Tribune*, *Herald*, *Sun*, and *World*, and among these was a letter from Dr. Charles F. Chandler, Dean of the School of Mines of Columbia College, New York, which we feel sure will interest many of our readers who may not have seen it where it was originally published in the *Tribune* of April 4, and will therefore insert here.

SCHOOL OF MINES, COLUMBIA COLLEGE, April 2, 1892.

MY DEAR SIR: In reply to your letter I would say that I am glad to learn that the Alumni of Stevens Institute are taking an active interest in the affairs of their alma mater. The alumni of an institution should be well informed of its needs, and certainly they should be second to none in their interest in the development of the institution in which they have received their professional education.

I have always taken a lively interest in Stevens, partly from the fact that your distinguished President is one of my most valued

friends, and because I have been intimate with several members of the Faculty, and also because I have known what a grand work the Institute has been doing for technical education. I hear of Stevens men everywhere, filling successfully most important places as mechanical engineers. At the School of Mines we have always regarded the Institute as a companion, never as a rival. We have worked in neighboring fields, cultivating products that were not exactly the same. We have devoted ourselves to the education of civil and mining engineers, chemists, architects, etc., while Stevens has made a specialty of mechanical engineers.

Geographically we are both in the same great metropolis, although on opposite sides of the Hudson River, and we draw our pupils from the same locality. Stevens is, in fact, a New York school, though actually in New Jersey. I wish you all success in your move for enlarged accommodations, and I have no doubt that the efforts of the alumni in this direction will meet with the success that has characterized their undertakings in the past.

Very sincerely yours,

[Signed] C. F. CHANDLER.

To WILLIAM L. LYALL, Esq.,
Secretary Alumni Association.

ATHLETICS.

THE LACROSSE SEASON this year promises to be unusually interesting. The game has been quietly but steadily growing in popular favor as a collegiate and general athletic sport, and is to-day more firmly established than ever before. It possesses the two requirements necessary to make any sport permanent—intrinsic merit in itself and attraction for spectators. The game is exciting and picturesque, and the action never lags. From the moment the signal to begin is given till time is called, the ball keeps flying from one end of the field to the other, the developments are sudden and striking, and every man is in constant motion. As a scientific game, it affords fully as much chance for head-work and team play as base-ball and foot-ball, while it lacks the dangerous elements of the latter. Above all, it is probably the most healthful and beneficial sport now played.

The conditions under which the game will be played have changed somewhat since last year. The "Metropolitan League" of local clubs will not be reorganized this season. The "Brooklyn" team has been absorbed by the N. Y. A. Club, which has now perhaps the best team in the country. The "Corinthians" have joined the "Staten Islands," and the "Jersey Citys" have been merged into the "Lorillards." The latter teams have been much strengthened by the change, and there will be many close and exciting games during the season.

There has been no change in the triangular "Intercollegiate Association." It was thought at one time that the University of Pennsylvania might put a team in the field, but the hope has not been fulfilled. Cornell has taken up the game, and perhaps by next year will be able to apply for admission.

As regards our own team, it will require much hard work to fill the vacancies left by last year's men. New men will have to be trained to fill the positions of Howell, Smith and Atwater, and now it is announced that W. Cuntz and Post, our two strongest attack men will be called West, on thesis work, and will be able to play only in the league games. Their loss will be severely felt, and it will be hard to fill their places. It is, as yet, too early to decide what strength can be derived from '95, but her men are taking hold in good shape.

There has been considerable stickwork both on the campus and at the grounds, but regular practice will not begin till after examinations, when Giroux will be on hand again to coach the team. The season opens on the 16th with a game on the home grounds with the M. A. C. team. It is Captain Martin's idea to have two games a week on the home grounds, thereafter, and one away, on Saturday, in order "to make veterans out of the new men before the league games."

In making up the team special regard will be paid to making it as heavy as possible. "All other things being equal, the heaviest man and swiftest runner gets it."

Passing and body-checking will receive particular attention, and every effort will be made to develop the most harmonious team play. Sluggers and grand stand players will not be in it this year.

The following partial schedule has been arranged:

April 16, Stevens *vs.* M. A. C., at Hoboken.
" 23, " " Lorillards, at Jersey City.
" 29, " " C. C. N. Y., at Hoboken.
May 4, " " Lawrenceville, at Lawrenceville.
" 5, " " Staten Island A. C., at Hoboken.
" 10, " " Lorillards, at Hoboken.
" 18, " " Lafayette, at Hoboken.
" 30, " " Cornell, at Ithaca.
About June 4, " " University of Toronto, Can., at Hoboken.

The team will go up to Cornell directly after the Lehigh game. The Toronto team will play Cornell, Lehigh, Stevens, Johns Hopkins, and others, on its southern trip.

THE annual meeting of the "United States Intercollegiate Lacrosse Association," was held in Philadelphia, on March 5. Kingsley Martin, '92, represented Stevens; J. L. G Lee, Johns Hopkins; and Schuyler B. Knox, Lehigh. The election of officers resulted as follows: President, H. F. Cuntz, Stevens; Vice-President, Schuyler B. Knox, Lehigh; Secretary and Treasurer, T. L. G. Lee, Johns Hopkins. Executive Committee: Chairman, J. L. G. Lee, Brantz Roszel, Johns Hopkins; K. L. Martin, Stevens; T. H. Symington, Lehigh.

The revision of the playing rules was the principal business transacted. For the future the position of field captain will be abolished; the decision of the umpires on goals will be final; there will be two 45 minute halves and the umpires and referee will be chosen beforehand, as in foot-ball. The official rules will be published by the Lehigh lacrosse management.

The following schedule was arranged:

May 14, Stevens *vs.* Johns Hopkins, at Hoboken.
" 21, Jonns Hopkins *vs.* Lehigh, at South Bethlehem.
" 28, Stevens *vs.* Lehigh, at South Bethlehem.

THE base-ball men in the Institute met on February 24, to take action in regard to putting a team in the field this spring. Strong, '92, Merkel, '93, and Cuming, '95, were chosen a committee to organize and govern the team. Paulsen, '93, was elected captain, and chose Wilbur, '93, as manager. Promise of financial support has been received from Professor Denton, and quite a sum of money has been collected in the college.

Strong and Cuming will probably be the battery. The other positions have not as yet been settled.

The following games have been arranged:

May 4, Stevens *vs.* Rutgers, at Hoboken.
" 11, " " Mercurys, at Hoboken.
" 14, " " West Point, at West Point.
" 19, " " N. Y. University, at Hoboken.
" 25, " " Rutgers, at New Brunswick.

THE Athletic Association has appointed the following committees.

On Spring Games—Merkel, '93; Cuntz, '93; Hall, '94.

On Foot-ball League—MacKenzie, '93; Coyne, '94; Corbett, '95.

FOR forming a team to represent Stevens in the Intercollegiate Games: Merkel, '93; Hall, '94.

Stevens has never taken much interest in these games before, but this year an effort will be made to send a team.

THE "Intercollegiate Athletic Association" now consists of the following colleges: Amherst, Columbia, College of the City of New York, Cornell, Fordham, Harvard, Lafayette, Lehigh, New York University, Princeton, Stevens, Swarthmore, University of Pennsylvania, Yale, and Georgetown College, of Washington, D. C. H. F. Cuntz and A. E. Merkel represented Stevens at the annual meeting held at the Fifth Avenue Hotel, New York, February 27th.

THE lectures on Lacrosse by Captain Martin and Cuntz, '92, have been a marked success. They have been of value, not only to the new players, but also to those who have had a year or two's experience. The plan might well be extended to base-ball and foot-ball.

IT is a matter of regret that we have been unable to obtain the use of the armory. The permission would have been of great value in the future.

THE "St. George Cricket Club" has been broken up and the grounds will be leased again to the Institute, under certain conditions. We shall have the northern and western portions, with some tennis courts, and the use of the whole field for lacrosse games until the middle of June, and for foot-ball from the 8th of October. Mr. Smithson will have charge of the grounds as usual, and entire control of them during the summer. The rental is $200.

THE Senior Class has adopted a custom, which it is to be hoped other classes may see fit to follow. They have turned over their $10 deposit to the Athletic Association. This sum, of about $400, with an equal amount which the management is depending upon the Alumni for in the fall, together with the Association appropriation, will open the way for improvements in many directions. It is now recognized that the reason Stevens has not kept pace with other colleges is that she has stood still, while the others have progressed, adopting new methods of training and play year by year.

Now it is hoped that sufficient money will be raised in the fall to warrant the securing of a trainer and the establishment of a first-class training table. These improvements will make the men feel that they have something worth working for.

The advantage of an increased number of students will also be seen in the greater number of candidates for the team.

THE management of the Athletic Association has at last decided to endeavor to raise money for erecting a much needed grand stand upon the grounds.

INSTITUTE NOTES

THE HOBOKEN CONCERT of the Glee and Banjo Clubs was a most striking success. It was held at Odd Fellows' Hall on the 16th of March. Both clubs were in remarkably good form. In the case of the Glee Club this was largely due to Wm. B. O. Field's untiring energies in such a worthy cause; while Wm. O. Ludlow, and Nicholas S. Hill, Jr., likewise deserve great credit for the success. A. J. Post could not have done more in developing the Banjo Club, and his work was fully appreciated, judging from the applause following every single one of their selections. MacGregor, ex-'93, was welcomed on this occasion, and as first tenor assisted the club materially. Three solos were sung by Messrs. Hill, Torrey and Field, respectively, the last gaining wild applause. A topical song, rendered by Ludlow, Litchfield and Kollstede was decidedly *the* selection of the evening. Financially, there was also success, the clubs clearing $135.

THE GLEE CLUB made its first appearance after a lapse of nearly two years, at the Berkeley Lyceum, Wednesday, February 3. It was represented by eight men under the leadership of W. B. O. Field, who took part in a small play entitled "A Night with the Gypsies," given by an amateur company under the direction of Mr. Wendt.

THE BANJO AND GUITAR CLUB made their appearance at a smoking concert given by the Palma Club of Jersey City on February 18. They were repeatedly encored, in such an enthusiastic manner that the audience's appreciation of their efforts could not be questioned. On February 29 the Banjo Club was again invited to play at the Palma Club. After this concert the members remained to dance and spent a delightful evening.

ON FRIDAY AFTERNOON, January 22, a meeting was held in Professor Wood's room for the purpose of organizing a Sketch Club. Those present were Patterson, '92; Litchfield, '92; Douglass, '93; Merkel, '93; Braine, '93; Boody, '93; J. B. Hamilton, '94; Ellsworth, '94; Lawton, '94; Olmsted, '95, and Corbett, '95. At a subsequent meeting the following were elected to hold office for six months: President, Litchfield; Vice-President, Patterson; Secretary, Boody, and Librarian, Lawton.

THE '92 COMMENCEMENT COMMITTEE consists of Litchfield, Chairman; Ludlow, Strong, Law, Corbett and Hotopp. It is probable that a Class Day will be held, in which case the same committee will have charge of the arrangements for that celebration.

THE ENGINEERING SOCIETY elected the following officers for the second term: President, W. E. Strong, '92; Vice-President, L. Wæfelær, '92; Secretary, F. E. Law, '92. The Executive Committee consists of Ludlow, '92; Mackenzie, '93, and Braine, '93. The Membership Committee of Wilbor, '93; Merritt, '93, and Furman, '93.

At a meeting of the Society on Friday, March 11, E. R. Douglas, '93, read a very interesting paper on "The Construction of Howe Scales."

THE ANNUAL THEATER PARTY on the night of January 21 was a "howling" success. About 150 students marched down to Jacobs' Theater in a body, preceded by a drum corps. The play was "Ole Olson," a piece having many opportunities for the introduction of local "gags," all of which chances were duly taken advantage of. The Sophomores and Freshmen both claimed that they were most highly favored by the actors and actresses, and everybody who attended the performance was very well satisfied with the evening's fun.

THE STEVENS YACHT CLUB is in a flourishing condition. At a special meeting Dr. Thomas B. Stillman and Prof. A. M. Mayer were elected honorary members.

PROF. JACOBUS returned from Bermuda on February 15 much refreshed and with health improved by his two weeks' vacation.

THE STEVENS GUN CLUB was organized on January 28, when a number of men interested in shooting came together to form a society for the promotion of their favorite sport. W. J. Beers, '87, acted as chairman, and the following officers were elected: President, D. W. Blake, '94; Vice-President, L. Carter, '95; Secretary and Treasurer, E. P. Buffett, '94.

On February 4 another meeting was held, at which a constitution was adopted. The president appointed the following committees: Membership, W. B. Field, A. Church and E. A. Huppertz; Club Property, H. E. Griswold and F. H. Coyne; Auditing, W. J. Beers, H. D. Coleman and A. A. Dal Molin.

The charter members are: W. J. Beers, '87, D. W. Blake, '94, E. P. Buffett, '94, L. Carter, '95, A. Church, '94, H. D. Coleman, '94, F. H. Coyne, '94, A. A. Dal Molin, Sp., W. B. Field, '94, H. E. Griswold, '93, and E. A. Huppertz, '93.

At a meeting held February 12, Anderson, '94, Cameron, '94, Boody, 93, Lozier, '94, Hopkins, '95, Montgomery, '95, and MacKenzie, '93, were admitted to membership. H. E. Griswold was elected field captain, to preside at club matches, and H. D. Coleman, director, to act with the other officers on the Board of Directors.

Prof. Mayer, who is the author of "Sport with Rod and Gun," has been elected an honorary member, which is a fitting compliment to his ability as a sportsman. He is a crack rifle-shot and a champion fly-caster.

THE SOUTHERN CLUB held a meeting on February 2, and elected the following officers for the ensuing year: President, H. D. Whitcomb, '92; Vice-President, C. H. Hotopp, '92; Secretary and Treasurer, D. W. Blake, '94; Chief H. G. C., J. R. Wilkes, '93; Assistants to H. G. C., St. George M. Anderson, '94, and C. H. Hotopp.

THE STEVENS SOCIAL SOCIETY held its first dance of the season in the hall of the Stevens School on January 27. The music was good, the floor in excellent condition, and everybody who was there had a most agreable time. The chaperones were Mrs. Morton, Mrs. Stillman, Mrs. Bailliere and Mrs. Olmsted. Among those present were the Misses Lewis, Clinton,

Post, Abbett, Harrison, Cooper, Brewster, Southmaid, Weir, West, Johns, MacCormack, and Howe.

The second dance was given in the hall of the Hoboken Camera Club, on the evening of February 23, and was thoroughly successful.

THE PRESIDENT OF THE SENIOR CLASS has appointed Macdonald, Braine, Slocum, MacKenzie, Dear, and Inglis, of '93, to act as ushers at the graduation exercises of '92.

THOMAS C. JENKINS, formerly of '93, is in the Mount Claire shops of the Baltimore and Ohio Railroad.

KINGSLEY L. MARTIN, '92, delivered before the engineering department of the Brooklyn Institute, on the evening of February 9, a development of the paper on "The Hudson River Tunnel," which he presented to the Engineering Society last term.

THE JUNIOR BALL will be held on June 22, the night before commencement, at the Lenox Lyceum, in New York City. It is the intention of the committee to rent the lower tier of boxes.

DR. STILLMAN appointed a committee of three from the Sophomore Class to make up the questions for the second term examination in analytical chemistry.

H. S. L. VERLEY, formerly of '94, is taking a special course in electricity with Dr. Geyer.

THE SENIOR CLASS held their last dinner as undergraduates on February 25, at the Sturtevant House, New York City. Howard Gurney was toastmaster. In responding to the toast of "A Stevens Man," E. D. Litchfield remarked, among other things, that "Doctor Sellers has said that American engineers are the best in the world. History subtantiates the statement. Tell me, if you can, of any great fundamental invention produced and made practical by any but Americans and their ancestors and relations, the English. Who were they that developed the steamboat, the locomotive, the telegraph, the submarine cable, electric lighting? Who revolutionized the science of naval warfare? Who first used the screw for marine propulsion? Who at the present day are the greatest bridge builders, the greatest iron manufacturers in this, the age of iron, but Americans and Americanized foreigners?"

After reviewing the course of study at the Institute, he said that the reason our graduates are so much sought after by engineering companies is that at Stevens a man is taught the value of work.

The committee which arranged the dinner consisted of Wettlaufer, Hake, Gardiner, Hill, Waefelaer and Fernandez. The evening was most pleasantly spent and the occasion will linger in the memory of every man present long after he has left the Institute and gone out into practical life. As usual, the Juniors who are to act as ushers at Commencement, were the guests of the Seniors.

THE JUNIOR BANQUET, which took place at Morello's, in New York, on February 5, was a decided success. Franklin D. Furman, the president and toastmaster, filled his position most gracefully, and the various toasts were responded to in an able manner.

THE SOPHOMORE DINNER COMMITTEE was composed of R. E. Hall, G. P. Hodgman, William B. Field, St. George M. Anderson and J. B. Klumpp, and when the class assembled at Morello's on the evening of February 18, it was seen that they had performed their duties well. R. E. Hall presided at table, and among the many excellent responses to toasts there was one to "The College Press," in which the speaker, Mr. Lawton, referred to the great reputation of the INDICATOR, the *Link* and *Life*.

THE FRESHMEN had their banquet at Sturtevant House on March 3. After the substantial part of the dinner was over Toastmaster Cuming made some appropriate remarks and introduced a long line of orators, who spoke most eloquently on a great variety of subjects. The committee having the matter in charge consisted of Montgomery, Sumner, Smart, Corbett, Paulding and Raoul.

PROFESSOR D. S. JACOBUS delivered a lecture on "Experimental Illustrations of the Principles and Properties of Substances Applied in Modern Refrigerating Machines," at the Brooklyn Institute of Arts and Sciences, on Friday, March 4, in which a general description of the several types of modern refrigerating machines was presented by the aid of lantern slides and a working model.

Theoretical computations of the relative efficiencies and sizes of compression cylinders in machines employing different vapors were given, which were compared with results obtained from direct experiment. Near the close of the lecture experiments were made to show the boiling points at atmospheric pressure of the various volatile fluids used in refrigeration. Special experiments were given, in which a freezing mixture colder than 100 degrees below zero Fahrenheit was employed.

The theoretical deductions were mainly abstracted from work now being prepared by Professors Denton and Jacobus in revising Ledoux's work on Ice-Making Machines, and from an article by the same authors in THE STEVENS INDICATOR for January, 1892.

A similar lecture was presented by Professor Jacobus at the Franklin Institute on February 26, and a report of the same will appear in full in the journal of that society.

ON THE AFTERNOON of Wednesday, March 2, the Seniors started on the steamboat "Puritan," of the Fall River Line, on their New England Inspection Trip. Professor Denton was in charge of the party. On their arrival at Fall River the next morning, they visited the Globe Yarn Mills and the Richard Borden Mills, and then took the train for Providence, where part of the afternoon was spent at the Nicholson File Works. Friday morning was devoted entirely to Brown & Sharp's Machine Shops, and in the afternoon the class went to Pawtucket and saw the great pumping engines and the hair-cloth works, where there are some almost human

machines, and then journeyed on to Boston. On Saturday morning a visit was made to the Watertown Arsenal, and that afternoon and all day Sunday the party rested.

Monday they were on the go continually, visiting a sewage pumping station, the great power station of the West End Electric Road, and a cold-storage plant. On Tuesday Dr. Geyer took the class to Lynn, where the Thomson-Houston Electrical Works and the Thomson Electrical Welding Works were inspected. That evening they went on to Springfield, where the night was spent. Early the next morning they took the train for Holyoke, where they saw the practical operation of turbines and their manufacture, and then in the afternoon they started on their return journey to New York, where they arrived in the evening, tired out, but well satisfied with their week's trip.

ON FRIDAY, March 25, the Seniors went to New York with Professors Denton and Jacobus and inspected the "Consolidated" ice-making plant of the New York Steam Heating Company, and a De la Vergne refrigerating plant in East Eighteenth Street. Tuesday, March 29 Dr. Geyer took them to see the United Electric Light Station in East Twenty-ninth Street.

THE CLASS OF '92 started on its last inspection trip with Professor Denton on Friday, April 1. They stopped at Trenton, where the wire mills were visited, and then traveled on to Philadelphia. Saturday morning they inspected the William Sellers & Company machine shops and the Baldwin Locomotive Works, and the afternoon was spent at Cramp's Ship Yard, after which they returned home.

THE FOLLOWING COURSE of lectures was given to the Carriage Builders' School in New York:

First. February 17, "Force, Energy and Work." By President Morton.

Second. February 24, "Frictional Resistances." By Prof. J. E. Denton.

Third. March 2, "Mechanical Paradoxes." By Prof. J. B. Webb.

Fourth. March 9, "Color." By President Morton.

Fifth. March 16, "Paint." By Dr. C. B. Dudley.

MR. JOSEPH WETZLER, '82, Editor of the *Electrical Engineer*, on Thursday, March 31st, delivered an address to the Seniors on "Electrical Railroads." The lecture was well illustrated by lantern slides and was very interesting.

INSTITUTE PERSONALS.

'76.

GUS. C. HENNING will be the official representative of the American Society of Mechanical Engineers, at a conference to be held in Vienna in September of this year, for the unification of standard methods of testing materials of construction. Most of the German, Austrian and Swiss authorities on this subject will be in attendance.

Mr. Henning is particularly well fitted for this position, as he has been on the American Society of Mechanical Engineers' Committee, appointed to consider "Tests and Methods of Testing," and has made a most thorough study of the matter, both in this country and in Europe. A series of articles on "Testing Machines," written by him, appeared in the INDICATOR, Vol. VII.

'81.

JAMES B. LADD is with the Robert Poole & Son Company, founders and machinists, Baltimore, Maryland.

'82.

VERNON H. ROOD is Superintendent of the Jeanesville Iron Works, Jeanesville, Luzerne County, Pa.

'83.

ERNEST H. WRIGHT has severed his connection with Westinghouse, Church, Kerr & Co., and can be reached by addressing communications to Germantown, Philadelphia, Pa.

FRED. W. TAYLOR is General Manager of the Manufactures Investment Company, Mills Building, New York City.

FRANK A. MAGEE is the Boston representative of the Engineering Equipment Company, and of the Underwood Manufacturing Company.

'84.

H. DE B. PARSONS has been made a lecturing professor at the Rensselaer Polytechnic Institute, at Troy, to give a course of lectures lasting three months on the "Steam Engine." These lectures are more practical than theoretical, and are delivered twice a week, each lasting two hours. Mr. Parsons and Wm. B. Parsons, consulting engineers, have removed their offices from Broadway to 22 William Street, N. Y.

A. W. BRAINARD is doing business as manufacturers' agent, especially representing the Bristol Manufacturing Company, of Waterbury, Conn., with his office at 41 Dey Street, New York City.

CHARLES F. PARKER'S address is, care of Thomas E. Brown, Jr., Potter Building, New York City.

'85.

THOMAS G. SMITH is now consulting and contracting engineer, Room No. 11, Hammond Building, Cincinnati, Ohio. He is mainly engaged in the construction of engines and the erection of complete steam plants for electric lighting and power service.

WILLIAM T. CLERK has taken up architecture, and established himself at Santa Barbara. During the winter of '89-90 he pursued a special course in that line at Columbia, and then went West for his health. Success in every way has followed the steps taken. His address is now, Architect, Hopkins Block, 1003½ State Street, Santa Barbara, Cal.

A. G. GLASGOW is Engineer and General Manager of the Standard Gas Light Company, of the City of New York, whose works are at the foot of East 115th Street.

PAUL WILLIS' present address is 614 First National Bank Building, Chicago, Illinois.

'86.

WILLIAM R. KING is the Manager and Engineer of the Empire State Phosphate Company, Rock Mines, Citrus County, Fla.

G. R. METCALF is a consulting electrical engineer at 32 Liberty Street, New York City.

OTTO F. PFORDTE was married to Miss Frieda H. Tittel, of Dresden, Saxony, on Monday, February 15th, at Jersey City, N. J.

'87.

WHEN the class graduated on June 16th, 1887, it was decided to have a reunion after five years, and, as the time for that happy event is now drawing near, President Moeller has appointed a committee consisting of Quimby, Flack, Jenkins, McElroy and Bayles, to take charge of the affair. This committee has had a meeting, at which Quimby was elected chairman, and has written to all the members of the class asking for opinions on the most fitting manner of celebrating the occasion. A silver cup will be given to the "first born boy," and all competitors for this honor had better send their respective names and birthdays to R. N. Bayles, The C. & C. Electric Motor Company, 402 and 404 Greenwich Street, New York City.

JOHN LYMAN COX is Assistant Forgemaster at the Midvale Steel Works, Nicetown, Philadelphia, Pa.

J. DAY FLACK is Superintendent of Motive Power and Construction at the lamp works of the Edison General Electric Company, at Harrison, N. J. He took a leading part in the amateur circus performance given by the Orange Athletic Club, of which he is a prominent member. He will be married to Miss Helen Woodruff Finney, at the First Reformed Episcopal Church, New York City, on Tuesday, April 19th.

WM. E. QUIMBY is Assistant Superintendent of the John Patten Manufacturing Company, Mills Building, New York City.

HERBERT A. WAGNER is Superintendent of the Westinghouse Electric Lighting Company, St. Louis, Mo.

'88

HENRY A. BANG is at present located with John Roebling & Son, designing wire-working machinery. He is stopping at the Trenton House, Trenton, N. J.

G. CAMPBELL is located as Superintendent of the Colfax Electric Railway Company. Address Box No. 2600, Denver, Col.

WM. A. MAGEE is in the real estate business with his father, Thomas Magee, at 20 Montgomery Street, San Francisco, Cal.

JOHN V. L. PIERSON has gone to California to live, and has been in the southern part of the State about nine months. This spring he became a half-owner of the San Antonio Placer Mine, which is 9,000 feet above sea level, 16 miles from Claremont, Los Angeles County. The latter is his post-office address.

T. E. THEBERATH is Chief Electrician at the works of the United States Electric Lighting Company, Newark, N. J.

ARTHUR L. SHREVE was, on March 1st, appointed Assistant City Commissioner of Baltimore, and will have charge of about a million dollars worth of new paving, sheet asphalt, asphalt block and granite block, to be done there this year. The appointment is for two years from the above date.

T. A. VAN DER WILLIGEN is assistant to C. W. Whiting '84, in the Mechanical Engineering Department of the Calumet and Hecla Mining Company, at Calumet, Lake Superior, Michigan.

'89.

ERNEST M. ROSENBERG is at present located with the "Yale & Towne Manufacturing Company, Stamford, Conn.," but is residing at 784 Lexington Avenue, New York City.

LOUIS B. BONNETT'S address is Assistant Corresponding Secretary American Society of Civil Engineers, 127 East Twenty-third Street, New York City. He is also Secretary of the Elizabeth Wheelmen.

RICARDO J. ECHEVERRIA and WILLIAM C. HAWKINS are engaged in engineering work in Costa Rica, with headquarters at San José, the capital.

IRA F. WORTENDYKE is Assistant Superintendent Jersey City Gas Works, Sixth and Provost Streets, Jersey City, N. J.

'90.

ALBERTO C. ATRISTAIN and MISS SOLEDAD RIOS were married on the 29th of February at the "Sagrario Metropolitano" (Metropolitan Church), City of Mexico.

ALFRED NATHAN is with the Blake & Knowles Steam Pump Works, 95 Liberty Street, New York. His city address is 22 East Seventy-second Street.

H. P. JONES is engaged in the designing of annealing plants, employing the "Jones Annealing Process." His business address is 35 Spring Street, Hartford, Conn.

G. A. TRUBE is with the Illinois Steel Company, South Chicago, Ill.

WILLIAM N. CARLTON is at present representing the Link Belt Engineering Company in Buffalo, N. Y., and is also engaged in mechanical engineering work. He writes that he is *not* starving to death.

ALFRED R. WHITNEY, JR., is General Manager of the Puget Sound Wire, Nail and Steel Company, at Everett, Washington. A local publication, among other things, says: "It is the intention to erect mills having a capacity of 400 kegs of nails of 100 pounds each per day, or 120 tons per week. It is expected that by May 1st over 200 men will be employed in this bee-hive of industry, which will then be in full working order. The General Manager, A. R. Whitney, Jr., is a young man of genial qualities and excellent business capacity."

'91.

BENJAMIN W. CARLL will leave the Dame & Townsend Company on April 1, and be temporarily located at Northport, Long Island, N. Y.

ALBERT W. ERDMAN is Assistant Electrician at the American Telephone and Telegraph Company, 18 Cortlandt Street, New York.

CHAS. B. HODGES has a position as Draughtsman with E. D. Leavitt, M. E., E. D., in Cambridgeport, Mass.

J. HENRY LIENAU is located with the "American Sugar Refining Company," Commercial Street, Brooklyn, E. D.

ALEXANDER DOW is helping to design some new machines for setting and distributing type for the American Type Setting Machine Company, Boston. His permanent address is 25 East Seventy-seventh Street, New York City.

H. J. SCHUMACHER is with the Brown & Sharpe Manufacturing Company, Providence, R. I.

F. N. SANBORN is in the employ of the Manhattan Electric Light Company, Eightieth Street and Avenue B, New York City.

C. TEMPLE EMMET'S address is East Rockaway, Long Island, and he is in the employ of the Edison General Electric Company.

ROBERT A. HANN is located with the United States Electrical Company, Newark, N. J.

JOHN DARBY is draughting for the Link Belt Engineering Company at 19 Dey Street, New York City.

WM. A. FIELD has joined a colony of Stevens men. He is with the Illinois Steel Company, South Works, South Chicago, Ill.

EDWARD S. WUICHET is Vice-President of the Miami Vally Boiler Company, whose works are at Nos. 1002 to 1016 East Third Street, Dayton, O.

THE COLLEGE WORLD.

A BEQUEST of $150,000 has been made for the purpose of founding a college, which will be situated at Newport, R. I. It is to be called Coles College.

A NEGRO UNIVERSITY will be founded at Oklahoma, with an endowment fund of $1,000,000, presented by William Astor.

WILLIAMS COLLEGE has been given a new laboratory, costing $50,000. The donor is Mr. F. T. Thompson, of New York. The college will hold its 100th Anniversary in 1893.

THE new site of Columbia College is between Morningside Park and Amsterdam Avenue and the lines of One Hundred and Sixteenth and One Hundred and Twentieth Streets.

THE Princess Kainli, of Hawaii, intends to enter Wellesley this spring.

VASSAR COLLEGE has become so crowded that a new residence building has become necessary, and is to be built.

YALE'S NEW GYMNASIUM, when completed, is expected to be the finest and most elaborate building of its kind.

THE University of Chicago will pay its head professors $7,000 a year as salary. Its library already consists of over 50,000 volumes.

AT Harvard $80,000 are spent annually for athletics.

NAPOLEON is said to have modeled the University of Paris after Alexander Hamilton's plans for the University of New York.

THE three largest libraries in the world are at London, Paris and St. Petersburg. They contain, respectively, 2,290,000, 1,500,000 and 1,000,000 volumes.

THE Moslem University, at Cairo, is the largest ih the world, having 370 instructors and 10,000 students.

HARVARD has a student over 77 years of age.

OXFORD UNIVERSITY will send an eight-oared crew to the World's Fair, at Chicago, provided there will be crews from American colleges to compete with it.

THE total membership of Greek letter societies in American colleges is estimated to be about 75,000.

EIGHTY PER CENT. of college editors adopt journalism as their profession.

YALE's new dormitory is 160 feet long, 46 feet wide and four stories high; it will contain 26 double rooms and 22 single rooms. It will cost $125,000.

THE ENGINEERING NEWS PUBLISHING COMPANY offers the following premiums for the best graduating theses, open to any 1892 graduate in any Engineering course of any college of the United States or Canada. For the best three graduating theses: First premium, $75; second premium, $50; third premium, $25. For such other theses as may seem to deserve such recognition, Honorable Mention, accompanied in each case by two years' paid subscription to *Engineering News*. Competing theses must be sent in by the college authorities, ***not by the authors***, and must be sent in anonymously, bearing only some distinguishing mark. All theses competing for these prizes must be received at the office of *Engineering News* on or before July 20, 1892, and the awards will be announced on or before October 1.

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COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

VI.—LECTURE NOTES ON TRANSMISSION OF POWER BY COMPRESSED AIR.*

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THE subject for my lecture to-day will be first the transmission of power by compressed air. This is a subject that has already engaged the attention of your professors, and probably has been treated of in the regular course of your studies; but the possible application of compressed air as a means of transmitting power from Niagara Falls to Buffalo, a distance of 20 miles, has called forth expressions of opinion from men who have given a great deal of study to this subject, from those who, in fact, have made it their life work.

It is interesting to note that, of the various plans submitted to the International Niagara Commission for the utilization of the water power and its transmission to a distance, several of the schemes proposed were predicated on transmission of compressed air.

* Since the lecture here reported was delivered, information has been received in regard to the pneumatic plant at Birmingham, which goes to show that this installation has not been pecuniarily successful, and the company furnishing compressed air to the manufacturers of that town has been obliged to make an assignment. This, however, does not affect the Parisian installation, which is said to have been very much improved during the last two years, and better results have been obtained.

The success of the transmission of power from Lauffen to the Frankfort exhibition by electricity has turned attention from compressed air towards electricity, and it is probable that many of those who were contemplating the use of compressed air will find it to their advantage to employ electrical transmission as being more economical.

In Paris and in Birmingham, as well as in other cities in Europe, the system of transmission by compressed air has been so far developed as to warrant the capitalists of Europe adopting this system for the transmission of power through many other large cities in the face of the claims of electricians.

Before speaking of the existing examples, I would briefly mention the very plausible scheme that was submitted by Mr. H. D. Pearsall, of London, to use the water at Niagara acting as in the hydraulic ram to compress air without the use of pumps or ordinary air compressors. This might at first seem rather chimerical, but Mr. Pearsall does not use the pressure due to the head only to produce the necessary compression, but he takes advantage of the velocity of the water to produce the necessary pressure in a manner somewhat similar to the action of the ordinary hydraulic ram. The main difference between Mr. Pearsall's system and the ram of Montgolfier is that in the former's methods the valves are automatically controlled, and not depending upon the action of the current of water to close them. By this means the shock and hammering that is incident to the ordinary hydraulic ram is done away with.

Now, Mr. Pearsall did not come before the commission as a visionary schemer. He had already used his system to lift water and had proved that the efficiency of his system was close to that of the best turbines operating pumps. As his system differs so entirely from the ordinary compressor system, it would not be well for me to dwell at length upon it, as the subject could scarcely be satisfactorily presented in a single lecture.

I wish now to call your attention to the installations which are in operation, and which are the basis of operations that have been made to the Cataract Construction Company in the utilization of the power of Niagara.

The Popp system in Paris originated with a project to operate all the tower clocks in the city of Paris by pneumatic pressure, one clock at the central station controlling the action of all other clocks wherever they might be situated. This scheme put in operation required the laying down of conduits for the air through the streets of Paris, and afforded the opportunity of furnishing some portion of the compressed air to those people who might wish to use power small quantities, such as running sewing machines and other light work, and from this primary use of it grew the extensive installation which is now not only in operation, but being added to year by year

to an enormous extent, furnishing power to engines of over 100 horse-power each in various parts of the city.

Professor Riedler, of Berlin, has also given a great deal of attention to the subject of improvement of compressing machinery, and in the presentation of the Popp system to the Niagara Commission he accompanied his proposition by the detailed report of certain carefully conducted experiments tried with the extensive plant existing in Paris.

The proposals that they sent in were based upon practical experience, and the whole of the compressed air works at Paris are placed at the disposal of the Cataract Construction Company, to enable them to confirm the results reached by Professor Riedler, provided that such experimentation does not involve too considerable disturbance of the regular service.

The establishment in Paris has already been in operation about 10 years, and, therefore, should be able to furnish much useful information. We might expect that what would be submitted would be that which had already been proved trustworthy by practice. It would enable the authors of the plan to show what had been done by compressed air, and from thence to reach the conclusions as to what can be done with it in the light of more recent improvements in compressors.

In Paris, the working pressure of air is from six to eight atmospheres, we will say from 90 to 120 pounds pressure per square inch; but 30 to 50 atmospheres or 450 to 750 pounds pressure per square inch, has been accomplished in the Paris experiments.

The great value of compressed air as the motive to drive machinery lies in the fact that it can be used in existing steam engines to very good advantage, but better still in those motors that are made especially for the use of compressed air. It also permits a very decided gain at moderate cost through the process of reheating the air after it has passed the meters and before it reaches the engines or other use to which it may be applied. You must bear in mind that heat applied to air tells directly upon its expansion, and that every degree of heat that is expended will yield a return in efficiency, the heat so applied being five times the value of heat used in making steam. This has all been thoroughly explained to you in the instruction that has been given to you on air engines and heat engines, but I would have you think for a moment of the many valuable applications which you can make of compressed air.

It is customary in towns where this air is laid on, as they say precisely as water is laid on to the houses for drinking or other purposes, to use it directly in operating the cupolas of foundries; not that they allow the whole volume of air to pass in from the mains that may be required for this purpose, but jets of air under pressure of, say, 90 pounds, are made to draw in with them the large volume of air required, after the manner of an injector. Where cold for refrigerating purposes is required, the compressed air can be made to do useful work, and passing from the engine into the cooling chambers reduce the temperature to the required degree for the preservation of food substances, such as meat, vegetables, etc. This in Paris forms a considerable part of the use to which compressed air is applied.

In operating lifts in houses and hotels and warehouses, compressed air is not made useful to work an engine, but acts upon a surface of water, and the water in turn acting upon a ram below the platform, accomplishes the hoisting without the consumption of more water, merely allowing the water to flow in and out again and be alternately put under pressure of air or the pressure removed from it, so that the advantages of the hydraulic lift are obtained by the direct action of air upon the water.

Smith's fires are also blown by the compressed air blast, using the jet principle of blowing.

The Houses of Parliament in London have a very admirable sewerage system, operated entirely by compressed air, which is so thoroughly automatic in its action, having no machinery to put in motion and be clogged by the matter passing through the sewer pipes, that the process requires no attention whatever. In fact, while I was in London, an investigation was made of the automatic compressed air sewerage applied to the Houses of Parliament, and it was found that all the passageways leading to the machinery were so clogged by cobwebs and accumulated dust, as to indicate clearly that no human being had been near any of this machinery for a very great length of time, and yet it had worked with the steadiness of clock-work.

Ventilation is assured and accomplished by compressed air without the intervention of fans and other moving machinery. Public buildings receive their required quantity of fresh air on the jet system. A small quantity of the compressed air carried in on the jet system is used either for cooling or heating purposes.

Tram cars are being operated by compressed air to considerable advantage, and one system, that of Hughes & Lancaster, of Birmingham, contemplates an ingenious process of recharging the reservoirs on each car by an automatic device which enables the car to take a charge of air as it passes the station without actually stopping, thus enabling cars with only 50 cubic feet of capacity in the storage reservoirs to make long runs, the supply stations being located near or far in accordance with the grade of the road and the weight of the service upon the road, the stations being closer together on ascending grades than they are upon the level. I have seen this in successful operation and have noted the ease with which the operator on the tram car can make and break connection even when going at very considerable speed.

The installation at Paris was made in the infancy of the art of compressing air and has passed through various stages indicating the improved knowledge acquired by time.

Besides this there are accessible the results of many of the air compressors that have been used in mines, notably those at the Mt. Cenis Tunnel, but it is a well-known fact that in many of these instances where compressed air has been used in the mines, the effective horse-power has been but 20 per cent. of the developed power of the steam used to compress it, so that we have a chance to study the action of the Colladon compressors as used in the grand work of the St. Gothard Tunnel, where the work was eventually done, though the loss of power in the compressors was more than 100 per cent. of the effective power transmitted to the mines.

Other compressors in use in Paris enabled Professor Riedler to study the action, and he has given us the result of the Sturgeon compressor, as designed for Paris, and of the Colladon, as well as the more improved machinery now being put into use and designed by Professor Riedler. He shows the diagram of the Sturgeon compressor, with a loss of 94 per cent.; of the Slide-Valve compressor, with 38 per cent.; of the Colladon, 41 per cent. With these imperfect compressors, from 50 to 70 per cent. of power is lost before the compressed air enters the mains and before the transmission of power can be spoken of. In Paris, several systems of air compressors have been tried at the Central Station, Rue St. Fargeau, three of them on quite an extensive scale. There are, first, the Sturgeon compressors, built by Paxman; the Colchester, with six engines, of 350 horse-power each. These compressors were defective and gave

much trouble. The results obtained from these compressors, according to four years' experience and the extensive trials of Professor Gutemuth, are that one indicated steam horse-power compresses 7.5 cubic meters per hour, but six atmospheres pressure in the main is equal to 265 cubic feet to 90 pounds in the mains. The second, the Francoise, built by John Cockerill, in Seroeing, 65 engines, of 450 horse-power each. With these compressors, one indicated horse-power compresses 8.5 cubic meters or 300 cubic feet per hour to six atmospheres or 90 pounds final pressure.

For the new central station, the Quai de la Gare, of 10,000 horse-power, now in consideration, the Riedler patent compressors have been adopted. Riedler's system consists chiefly in combined compression with patented mechanically controlled valves and some other important details.

In order to obtain complete experience with this compressor system before starting the large 12,000 horse-power compressors at the new central station, one of the five Cockerill compressors was rebuilt according to Professor Riedler's plans, and the result was a noiseless working, complete cooling, good draining of the compressed air and higher speed and higher efficiency than had been before obtained. The engine, it is now claimed, is doing very nearly twice the work it did formerly with 40 per cent. more efficiency than with the Paxman compressors. This new Riedler compressor with one indicated horse-power compresses 371 cubic feet per hour of ordinary atmospheric air to 90 pounds pressure in the main. The mechanical efficiency of this engine has been computed by Professor Gutemuth to be 87 per cent.

Each of these compressors consists of three cylinders, two of which are low-pressure cylinders, aspirating air and compressing it to 38 pounds pressure, the high-pressure cylinder completing the compression to over 90 pounds.

In adopting the size of the cylinder—viz., of 4 to 5 feet stroke, Professor Riedler had before him the blowing engines that exist, for instance, at the steel works of Adal Berthutte, at Kladno, for 5 feet stroke and working with cylinders 4 feet in diameter at 30 to 35 pounds air pressure, which engines have been running for nearly five years almost continually with a piston speed of 1,000 feet per minute without causing any trouble. At this speed they are running with self-acting valves, and the controlled valves would permit a higher speed than where the valves close with the blow.

I had an opportunity while I was in England last year to visit the compressed air works at Birmingham, designed by Mr. John Sturgeon, assisted by Professor Lupton. In this case the compressors are single-acting vertical engines, and the cooling is effected only by water passing around the outside of the cylinder, Mr. Sturgeon claiming it as more important that the air shall enter cool, and, in his estimation, this can be most easily effected by having the cylinder cool into which the air passes.

For this reason he objects strenuously to the use of double-acting compressing cylinders, and so arranges his vertical compressors that there is no clearance at the end of the stroke.

He has made the valve by which the air is discharged on the cylinder as large as the cylinder itself, in point of fact being the upper cylinder head. This is lifted at each stroke of the cylinder by the plunger coming in contact with it, if it has not already been lifted and displaced by the air which is under compression.

The cards taken from those cylinders that were constructed first show a very considerable power required to lift this valve, and relief from overwork was given by studding the whole surface of the large valve by many smaller ones each closed by a light spring affording relief to the air in passing out.

The reason for making the whole end of the cylinder one large valve was to entirely do away with all clearance space, so that the entire quantity of air displaced by the plunger shall pass into the receiver.

The plant that is now operating in Birmingham has not been entirely a commercial success owing to the fact that they named too low a price for their compressed air per cubic foot to some of the earliest applicants for power in order to induce them to try it, but as soon as the compressed air had entered into common use and its advantages were so apparent to users, then they were enabled to charge a fair price for the air and yet be quite inside of what it cost the producers to create the same amount of power themselves when the loss incident to transmission in each establishment was taken into consideration.

Birmingham is a great manufacturing town, and the part of Birmingham that has been given over to the air company for the experiment in transmission had been not many years ago a place for residences of probably a humble order. Houses built for residential purposes have been converted into manufacturing establishments.

Manufacturing business of various kinds have grown from small beginnings to quite extensive industries; not by the erection of well-arranged houses for the purpose, but by the accession of one existing house to another one in groups.

The cost of transmission through such dwellings was very considerable, and all kinds of devices were made use of to effect this transmission, but chiefly the power was carried by means of lines of shafting, consuming in the manner in which these lines of shafting were erected, in most cases, more than 50 per cent. of the power given by the steam engine.

The very many difficulties that obtained in this transmission of power lent themselves to the more economical transmission of power by means of compressed air, and it only needed a few experiments to prove the excellence of the system as far as convenience was concerned.

The difference between Birmingham and Paris, in regard to the introduction of such a system as this, was markedly shown in the municipal regulations governing the two cities. Paris, a much-governed city, has thrown around the introduction of steam many restricting laws that make independent boilers and steam engines in domiciles quite a costly mode of obtaining power. On the other hand, Birmingham is a city so given up to manufacturing interests and where the manufacturers themselves dominate the governing of the town, and the city itself having been already classed among the best-governed towns in the world in some respects, there has been little or no impediment offered to the free use of steam power, as it is manifestly to the advantage of the city to encourage its manufacturing industries in every way possible.

With comparatively cheap steam in Birmingham and very costly steam power in Paris, the introduction of compressed air in the latter city would naturally have been attended with more profit than in Birmingham.

Those who are now using compressed air in Birmingham, and using it satisfactorily, say they took it as the best thing that was offered to them, but the introduction of the compressed air into the city of Birmingham was opposed by the authorities more strenuously than in Paris, where it seemingly was encouraged.

It appeared quite evident in my examination of the introduction of compressed air into Birmingham, that the municipal authorities had hedged it in with all the opposing and limiting

ordinances that obtained with such force against steam in Paris, holding that if the system was good enough to exist in the face of all this opposition, in the face of all these difficulties that were imposed to protect the interests of the citizens at large as against a corporation seeking an extended franchise, the mode of transmission must be a very good one indeed, and in fact, it has proved itself to be a great advantage to the part of Birmingham now supplied with compressed air.

There has been a very considerable increase in the number of establishments that have adopted the use of compressed air in Birmingham, but it has not yet extended into all classes of industries so thoroughly as it has in Paris.

In regard to the use of compressed air in Paris, I have received from Mr. Popp, the originator of the compressed air system in France, a list of the different industries to which it is applied, showing that the power used in the motors varies from the small amount required to move the hands of a clock, up to as much as 200 horse-power in a single machine. The list of the industries and the amount of power applied to each I give in the table on page 204.

In Birmingham a very considerable increase of power per cubic foot of air introduced is obtained by reheating in a very crude way, by passing the air through tubes over an ordinary fire of coke. This requires little or no attention, and gives to the air a sufficient amount of heat to allow the expansion to be attended with no such low temperature as would accumulate ice about the engines.

In one establishment visited by me I saw engines from 70 horse-power down to one or two used in the one place, and these had taken the place of the original method of transmitting the power by shafting from one building to another.

In selling this compressed air to the consumers in Paris, they adopt a form of meter, as they also do in Birmingham, but in both cities there are individual cases where the power is measured by the use to which it is applied, as for instance, to a certain sized engine, and this only for want of a thoroughly reliable meter.

There is no doubt but that a field is open to the inventor who will give what is required in this direction—viz., a reliable method of measuring the air that will be not too costly in dealing with very large quantities.

The different uses to which compressed air is applied, such as the direct use in cupolas and the blowing of fires in blacksmiths'

Motors Driven by Compressed Air.

System, Victor Popp.

Uses to which it is Applied up to April 13. 1891.

Industries	Force in Kilogram-meters.		Force in Horse-Power.						Total.	Observations.
	6 to 24 1/12 to 1/3 H.P.	25 to 75 1/3 to 1 H.P.	2 to 6.	7 to 12.	13 to 25	26 to 50.	50.	100.	150.		
Lithographical presses	4	30	25	2	1	..	..	..	..	62	Total Power Estimated at 4,050 H. P.
Printing establishments and stereotyping	2	4	4	..	..	2	2	..	..	14	
Circular and other kinds of saws	3	17	34	3	2	..	..	..	..	59	
Machines for cutting cloth to pattern	8	21	2	..	..	..	..	..	..	31	
Pumps	..	..	2	1	..	..	..	..	..	3	
Grindstones	4	15	2	..	..	..	..	..	..	21	
Turning lathes	17	41	51	9	..	..	..	..	..	118	
Rolling and shearing machines	4	6	6	..	..	..	..	..	..	16	
Refrigeratories, ice houses	2	1	1	3	..	..	..	..	..	7	
Mills for coffee roasting, sifters and distilleries	4	9	1	..	..	..	..	..	..	14	
Shaping, drilling and planing machines	..	7	8	..	..	..	..	..	..	15	
Hydroextractors	6	8	4	..	..	..	..	..	..	18	
Sewing and ruling machines	51	2	7	..	..	..	..	..	..	60	
Mincing, pulverizing and mixing machines	..	22	7	..	..	..	..	..	..	29	
Machines to perforate and to sand	2	3	1	..	..	..	..	..	..	6	
Machines for cutting and carving	4	5	1	..	..	..	..	..	..	10	
Machines for weaving and twisting silk	1	1	..	..	..	..	..	..	..	2	
Galvanoplastic machine	..	2	1	..	..	..	..	..	..	3	
Embroidering machines	10	..	..	..	..	..	..	..	..	10	
Shears and cutters for tin plate	3	2	1	..	..	..	..	..	..	6	
Turbines and ventilators	2	4	11	..	..	..	..	..	..	17	
Lace machines	..	4	..	..	..	..	..	..	..	4	
Machines for carding, rolling and scouring	2	3	5	..	..	..	..	..	..	10	
Comb making	..	..	..	..	1	..	..	..	..	1	
Dynamo electrical machines	5	1	6	1	1	2	..	..	..	16	
Static electric machines for doctors and dentists	3	1	2	..	..	..	..	..	..	6	
Machines for making soda water	..	..	1	..	..	..	..	..	..	1	
Doughmaking, kneeding and rasping machines	..	3	1	..	..	..	..	..	..	4	
Woodturning machines	1	1	6	..	..	..	..	..	..	8	
Sifting and polishing machines	..	2	..	..	..	..	..	..	..	2	
Pasteboard, envelopes and pasting machines	2	1	1	..	..	..	..	..	..	4	
Shoemaking machines	..	1	2	..	..	..	..	..	..	3	
Hot air stoves	..	..	..	2	2	..	..	..	..	4	
Machines for pumping beer and wine	22	..	..	..	..	..	..	..	..	22	
Lifts and pavement hoists	..	..	6	4	10	..	..	..	..	20	
Machinery for ventilation	..	33	..	..	..	..	..	..	..	33	
Motors to drive dynamos (et chambres poides)	..	1	10	9	10	1	20	1	4	56	
Blowpipes	96	..	..	..	..	..	..	..	..	96	
	258	251	209	34	27	5	22	1	4	811 Users.	

shops, necessitates its being delivered to the establishments not by horse-power but by cubic foot, delivered exactly in the same manner as delivering ordinary illuminating gas to houses, but the quantity being so very much greater precludes the use of the same form of meter in both instances.

The meter that is now being used in Birmingham with the most satisfaction is one that is depending upon the rotation of a fan under the action of the passing air and is not assumed to be as accurate as if it could give volumetric measurement.

The question is now before the people of this country as to how power can be supplied in large cities. The New York attempt of carrying steam through the cities for power and heating purposes has had many difficulties to contend with, and is very far from being an acceptable method of transmission.

We have in some of our cities manufacturing establishments that are so extensive as to quite pass beyond the areas bounded by the city streets. The city of Philadelphia has in one district between Broad Street and the Schuylkill River and near the line of the Reading Railroad, an immense number of manufacturing establishments that have congregated in that locality on account of railroad facilities and the cheap coal that is brought in over the Reading Railroad. Here we have the great locomotive establishment originated by Mr. Baldwin, the Baldwin Locomotive Works, the establishment of Wm. Sellers & Co., Incorporated, Mr. James Moore, of the Bush Hill Iron Works, the great wheel works of Whitney, the shafting establishment of G. W. Cresson. These establishments in some cases occupy an entire city block, in others two, in others four, five or even six city blocks; an extension, for instance, of the Baldwin Locomotive Works, has been carried so far that it has passed around and beyond other large establishments, so that their industries are scattered over quite an extended area and give one of the best examples of what might be done by the transmission of power from some central station to these various separate buildings that now cannot be connected in the ordinary manner.

Where an establishment like the Baldwin Locomotive Works requires a large amount of steam for heating and running of steam hammers, besides the engines that give motion to the machinery, and where the total horse-power required is 2,500, we have an example of an instance where power introduced by compressed air or electricity or any of the new forms of transmission, would add very

much to the convenience and efficiency of the establishment. The room taken up by the boilers is great; the cost of hauling and the room required for storing coal, as well as the removal of the ashes, present themselves as questions that can only be settled by some economical method of producing power and transmitting it to a considerable distance without too much loss in the transmission.

The most recent communication that I have from Switzerland is from Oerlikon Works, where I learned at my last visit that they contemplated driving each separate part of their establishment by means of electricity generated from some central station and that they were then taking out the lines of connecting shafting in order to get rid of the loss by that mode of transmission. But now they tell me that they are preparing to utilize a water power that is 15 miles away from Oerlikon and their works. They will bring the power in the form of electricity at a high voltage and by the use of alternating current motors of peculiar construction. It is claimed as a result of the experiments made by Mr. Brown at Oerlikon that they can do this work without any considerable loss in transmission, and certainly the experiments that have been tried by those who have been in advance in using the alternating current for the transmission of power show that this loss even at a distance of 15 miles will not amount to as much as 5 per cent., and may be less.

It seems to me that what is wanted at the present time is not so much a single system of transmission either by compressed air or by electricity alone, but what should be accomplished would be some mixed system where the power can enter an establishment in the form in which it is to be used without undergoing any other transformation. Thus, as electricity is needed for lighting, and as compressed air forms the best means of working steam engines or steam hammers without change, and as they both can be originated with ease in the same establishment from the same steam engines, it would be well to have the transmission by electricity and compressed air conjointly. But yet, in studying this question and determining to what extent such an enterprise might be carried, we find it claimed by those who have done the most with compressed air that it is cheaper to transmit the power in that manner than it is by electricity, and that the whole of the power transmitted by compressed air would more nearly meet the requirements of manufacturing establishments than when wholly transmitted by electricity,

on account of the many uses to which the compressed air can be applied directly without any other conversion.

While the Paris installation is mainly of compressed air, yet it has the lighting of a certain part of the city to do with electricity, and in that case from one central station they transmit the power in the form of compressed air to the point where their dynamos are to be used, and they then drive their dynamos by compressed air engines rather than place the dynamos in the same establishment with their compressors and transmit by electricity direct.

There is an immense field for research yet in the method of heating compressed air. Professor Unwin suggested as an instance that in the use of compressed air gas might be burnt within chambers joining the compressed air or in the pipes leading to the engine, so that the whole of the products of combustion might pass into the meter and through it.

Others have suggested the advantage of heating the compressed air by means of steam, claiming that steam injected with the compressed air in small quantities will not only effect the heating but will give the necessary moisture to the air to favor the smooth running of the engines.

You are now about to begin the practical use of the education you have received in this school as engineers at a time when these questions of transmission are being talked of and where the air is filled with the rumors of what is going to or may be accomplished, and you will find abundant use for the information that you have collected while at school, and plenty of opportunity to exercise your talents as men familiar with experimental methods.

The transmission of motion by hydraulic power which was first prominently introduced into practice by William Armstrong, who has since been knighted and finally raised to the peerage in recognition of the valuable services rendered to engineering, calls for a knowledge of some of the methods that have obtained in practice and have been followed by the best results. My own experience with the construction of hydraulic lifts and cranes dates back to a time when this mode of transmission had been little used in this country.

About the year 1857 I had an oportunity to design extensive hydraulic transmitting machinery for the firm of Asa, Whitney & Co., car builders in Philadelphia, and at that time followed the lines laid down by William Armstrong in his work, though in point of fact

much that Armstrong has done was anticipated by Perkins and a great deal of the work that has been done in this direction has not been characterized by as exact knowledge of the principles involved as might have been expected.

Whether we are working with water under pressure or with air under compression, the question of packing is an important one and requires careful study to perfect and apply the devices that will be found to be the most durable. Machinery that is operated by water under a pressure of only about 500 or 600 pounds to the square inch, may be designed to use a packing similar to a steam engine; in other words, ordinary hemp packing will answer a better purpose than cupped leather, as being more durable and more readily applied in practice. But it was not until the pressure was carried up much higher, up to between 4,000 and 5,000 pounds per square inch, that the real difficulties of securing a packing that would last and be durable were encountered. Not only were the difficulties in packing encountered, but the difficulties also in making cylinders which would stand the pressure applied.

The early wheel presses for pushing wheels onto their axles were made with screw power operated by gearing. Some such machines are in use at the present day that have been durable and lasting, but the disadvantage of them is that they do not indicate of themselves the exact amount of pressure that is being supplied, and they have to be supplemented by a hydraulic cylinder that will record the pressure obtained by the screw. The more recent machines for this purpose, wheel presses, are simply modifications of the Brama press.

My own improvements in this form of machine tool were in the direction of simplicity in construction and fewer parts. I found that it was impossible to make a cast-iron hydraulic cylinder forming part of the upright of a wheel press that would last many years, no matter how carefully the cast iron of which it was made was selected, nor how carefully it was founded.

Water at 5,000 pounds pressure per square inch will sooner or later find its way into the pores of the metal and gradually as it extends deeper in will so enlarge the interior of the metal submitted to the hydraulic strain as to result in fracture.

To avoid this I propose the simple device of lining the hydraulic cylinder with copper so placed that the sheet of copper should be continuous and not pierced by any hole to admit the water

to the interior. This was easily done by making the back end of the cylinder open, but with an opening of smaller diameter than the cylinder itself, and lining the whole length of the cylinder with a sheet of copper carefully rolled in and burnished to a proper degree of finish by mechanical devices, then using two plungers, one plunger being the movable one with its cupped leather packing at the back end of it in the cylinder; the other plunger a mere disk with a hub on it projecting through the back end of the cylinder and it also fitted with cupped leather packing. The water or oil that is to operate the press is made to enter through the packed plug forming the back end of the cylinder which is a mere sealing block to close the back end of the cylinder and prevent the fluid passing outside of the copper lining.

This method of lining was found to work so well that it has been applied to many hydraulic presses now made, as to the cylinders of forging presses. Any metal cylinders required to stand hydraulic pressure may be lined with copper or brass in this way to advantage.

You will find in studying the literature on this subject that Mr. John Hick's experiments on the friction of packing have become the standard, and he probably threw more light than any one else, on not only the friction, but the durability of leather packing for hydraulic purposes.

There is, however, an important consideration, and one to which I wish to call your attention—viz., the durability and the method of determining the durability of any kind of hydraulic packing. Some years ago experiments were tried on a hydraulic wheel press rigged up as a testing machine for this purpose. The pump plunger, made on the Perkin's plan of pump, the cylinder of which is made double-acting with only two valves by the piston-rod of the pump being one-half the area of the piston itself, so that the plunger in descending expels only half the quantity of fluid contained below it, the other half passing up and surrounding the plunger or piston-rod, when upon the up stroke of the plunger to draw a fresh supply of water below the piston-rod the upper annular space is emptied with a discharge equal to that which came from the down stroke of the plunger. This form of cylinder and plunger, invented by the late Jacob Perkins, has come into extensive use both in pumps and in hydraulic motors. Its principle is also shown in many of the hoisting machines and lifts and eleva-

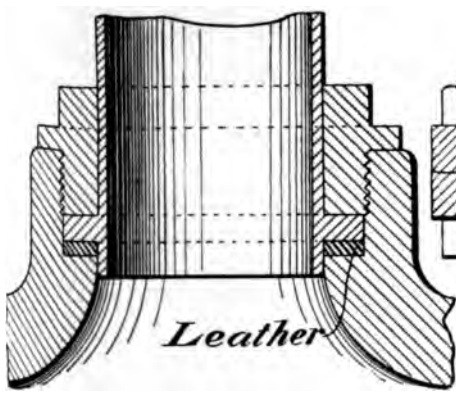
tors that are now in common use in warehouses in America and England.

The experiment that I am leading up to in reference to the durability of packing tried with a pump of this kind was conducted in the following manner: The ram of the plunger was blocked to prevent it advancing, a safety valve carefully loaded and corrected by a standard pressure gauge was adjusted to allow the fluid driven in by the pump to escape under the required amount of pressure, the greatest pressure being that of 5,000 pounds to the square inch. Packings of various kinds and shapes were used one after the other in this plunger, an ordinary revolution counter was attached to the machine which would give the number of strokes made by the pump, and as the length of the stroke was exactly 6 inches, each revolution indicated 1 foot of motion of the packing, and 100 revolutions per minute meant 100 feet per minute of the rubbing motion of the leather packing against the polished surface of the interior of the pump. After a long series of experiments with many different forms and manufactures of leather packing, the conclusion was reached that the depth of the cupped leather has little to do with its tightness or its durability; that when there is a pressure of 5,000 pounds to the square inch continuously applied to a cupped leather packing, it has seldom been known to exceed a durability greater than about 7 miles continuous motion to each packing applied. Seven miles of packing, or in round numbers, 37,000 feet of motion is sufficient to wear out the packing when the speed of rubbing is at the rate of 100 feet per minute.

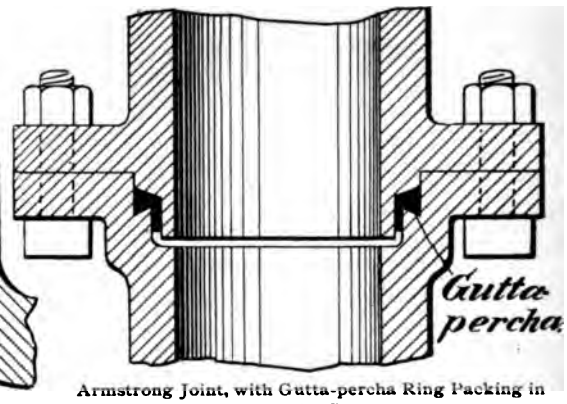
When you consider the action of various kinds of presses, you will find that many of them have a very considerable life of packing for the reason that the pressure at the maximum is only continued for a very short time, and is not complicated with rapidity of motion. Thus, if you take the example of an ordinary oil press, such as is used for flaxseed or cottonseed, these presses expel the greater quantity of oil from the ground seed, upon which they operate at a very low pressure, in fact, below 500 pounds to the square inch, with a final pressure of 4,000 to 5,000 pounds to the square inch applied to the ram after the great bulk of oil has been expelled and has flowed off. This results in a forward motion of the ram under the severe pressure of scarcely as much as one-half of an inch length of stroke, and that continued over probably a period of 15 to 20 minutes. Thus, if to such a press you apply the rule of 37,000 feet of motion,

as expressing the durability of the packing, and determine the number of strokes that will be made by the oil press in a day, you will find that, while the packing might be worn out in 370 minutes continuous pressure, or in perhaps six hours, yet this packing, occasionally used and moving such a short distance, would last for several years.

There are two kinds of joint packing to be considered with all hydraulic work. One is the joint packing that does not move; the other, in which the packing used in the joints is to prevent the outflow or escape of the fluid, is complicated by motion, as in the many joints used where pipes must be flexible to carry pressure from an accumulator to any portable hydraulic machine, as with portable hydraulic riveting machines. In the case of the stationary packing, the joint must be always so constructed that the tendency of the escape of the fluid shall be to drive the packing itself up to and against the escaping joint, and for this reason I would advise the leather washer which is to form the packing joint to be confined in the manner shown in the figure.



Showing Packed Joint for Pipe to Machine.



Armstrong Joint, with Gutta-percha Ring Packing in Triangular Recess.

In many cases it is found possible to avoid the use of complicated joints of this kind by carrying the fluid under pressure through copper tubes made strong enough to bear the pressure, of small diameter, and coiled like a spiral spring to give flexibility to them. Many of the Tweddell riveters in use in England are fed through copper pipes that are flexible within the limits of safety to elasticity without any joints involving motion on the packing.

ANALYSES OF GLASS USED IN THE MANUFACTURES OF INCANDESCENT ELECTRIC LAMPS.*

BY DURAND WOODMAN, PH. D., '80.

IN the manufacture of incandescent lamps there is a certain percentage of loss due to what may be termed spontaneous breakage; lamps, apparently well made, cracking at some part without having been subjected to any shock or blow.

A reasonable amount of loss in this way is unavoidable, from one cause or another, but when a certain limit is exceeded some special cause is suspected, as carelessness in the glass-blowing department, want of sufficient annealing, and the like.

The difficulty often passes by during the efforts to control it, without any satisfactory explanation either of the trouble or the cause of its cessation.

The lamp bulbs may crack (*a*) where the platinum wires are sealed in, or (*b*) where the "stem" carrying the wires and carbon filament is joined to the bulb proper, or occasionally (*c*) where the exhausting tube is sealed on at the apex of the bulb.

In addition to the internal strains existing in any such glass work, the lamp bulb, when finished, is subjected externally to the full atmospheric pressure and to sudden heat strains from the instantaneous turning on of current, as occurs in perhaps a majority of lamps in use.

Considering this combination of forces tending to produce rupture, it is evident that differences in the glass used for the bulb and stem and consequent differences of co-efficients of expansion which, in ordinary glass work would not be of importance, will become manifest here.

Glass blowers know that similar grades of glass should be used together, but they are able to work up grades of glass differing in composition more than is permissible in incandescent lamps.

* From the *Journal of the American Chemical Society*, Vol. XIV., No. 3, with additions by the author.

I have had an opportunity to make some analyses of the glass used at a time when the percentage of spontaneous breakage was abnormally large, and when every care in making up the lamps, annealing, etc., was unavailing.

ANALYSES OF GLASS ROD, TUBE AND LAMP BULB.

	Rod, 108.	Tube, 109.	Lamp Bulb, 112.
K_2O	1.38	4.20	2.32
Na_2O	15.06	9.05	14.50
CaO	2.15	.....	6.40
MgO	0.70	.....	0.93
MnO	1.02	trace.	trace.
Fe_2O_3		1.65	1.45
Al_2O_3			
PbO	16.81	19.83	1.39
SiO_2	63.44	65.16	72.35
Cr_2O_3	trace.	trace.	trace.
	100.56	99.89	99.34

The large variation in the quantities of lead, sodium and calcium oxides, account for the differences in co-efficient of expansion which caused breakage in lamps made up from these grades of glass.

During the investigation, samples of glass of lamps by several different makers were analyzed; one of them, an English lamp, gave the following figures:

ANALYSES OF BULB AND STEM OF ENGLISH INCANDESCENT LAMP.

	Bulb, 115.	Stem, 116.
K_2O	5.20	6.14
Na_2O	9.20	8.10
CaO	5.41	5.05
MgO	.....	trace.
Fe_2O_3	3.70	1.10
Al_2O_3		
PbO	2.90	10.68
SiO_2	73.10	68.24
	99.51	99.31

This bulb was a very brilliant clear glass. No information was at hand in regard to the percentage of breakage in the manufacture

of these lamps, nor whether the large amount of lead oxide in the glass of the stem was intentional or accidental.

Another lamp (of American manufacture) was examined and found to be of the same glass throughout, as shown below:

	Bulb, 113.	Stem, 114.
K_2O	7.17	6.91
Na_2O	6.43	5.89
Al_2O_3	0.39	1.98
PbO	18.70	17.14
SiO_2	66.22	65.80
CaO	0.45	1.25
MnO, MgO, Fe_2O_3	traces.	traces.
	99.36	98.97

An opal glass used with the first three above mentioned, and two samples of lead glass obtained for possible adoption in manufacture were analyzed with the following results:

	Opal Glass.	Corning.	Macbeth.
K_2O	1.87	6.40	5.05
Na_2O	7.50	3.90	5.75
CaO	7.20	0.25	traces.
MgO	....	trace.	
ZnO	1.85	....	....
SnO_2	0.95	....	....
Fe_2O_3	trace.	0.50	0.75
Al_2O_3	4.43		
BaO	trace.	....	....
PbO	13.45	18.50	24.40
P_2O_5	trace.	....	....
SiO_2	61.55	69.50	63.80
	98.80	99.05	99.75

It should be said here that no proof has been obtained as to the possibility that some glasses of different composition may have similar co-efficients of expansion, certain constituents compensating each other, but as it is a simple matter to obtain glass of practically the same composition for all parts of a lamp or any other complex glass work, problems connected with the co-efficients of expansion need not be taken into consideration.

ON COMPOUNDING CENTRIFUGAL AND LOAD GOVERNING BY A ROTARY-PISTON VALVE.*

BY WILLIAM S. ALDRICH, M. E., '84.

THE matter of governing steam engines for uniform speed, and economy in the use of steam, becomes more difficult as the size of engine is increased. Especially exacting are these requirements in the electrical service, whether for light, power or railway work, with the extended use of marine engines of the vertical-inverted multiple-expansion type. These are directly coupled (or, at most, directly belted) to large multi-polar dynamos—two or more for each engine unit. The rotative speeds are consequently much higher than in the same type of engines at sea, and the boiler pressures are also greater. The concentration of great engine power, in a limited space, becomes a serious question in the construction of large municipal electrical supply plants, in or near the center of the area of distribution. These considerations, with the demand for economy, have led to the adoption of the marine engine in central station work.

The inherent difficulties of governing steam engines cannot be overcome. The only effective control of the steam supply is during admission, whether by controlling the pressure or the point of cut-off, or both. The variable driving effort on the piston, due to expansive working, the variable effect of the inertia of the reciprocating parts, and the variable crank efforts, can only be more or less met by the steadying action of a well-designed fly-wheel.

The nature of the problem presented—in view, especially, of marine engines in central stations—may be outlined as follows:

First.—The speed regulation to be as nearly perfect as the operation of the governing forces and of the regulating mechanism will permit.

* Presented at the San Francisco meeting, May, 1892, of the American Society of Mechanical Engineers, and forming part of Vol. XIII. of the *Transactions*.

Second.—The steam supply to be as directly proportioned to the external load as the mechanism of the steam engine will allow, by varying the mean effective pressure on the piston.

Third.—Automatic regulation of the point of cut-off alone; or, of all the events of the steam stroke, if desired.

Fourth.—The valve, valve mechanism and governor mechanism to be as free as possible of any needless frictional resistance, requiring a minimum power to alter their motions in sense, direction or magnitude.

Fifth.—The governing forces to be brought into operation upon any change of speed or of external load, or of both at the same time by *compounding* the centrifugal and the load-governing principles.

Sixth.—The centrifugal-governing forces to operate on the valve mechanism at a minimum required variation of speed.

Seventh.—The load, or dynamometric-governing forces, to be indirectly applied, and not through the intervention of mechanism by and through which the power is transmitted from the engine to the dynamo.

Eighth.—The instantaneous variations of the external load to be as immediately and positively felt at the valve as the load-governing mechanism will permit.

Ninth.—The variations, through any cause, of the driving effort on the piston and internal friction of the engine, as distinct from the external load variations, to be controlled by effective and sensitive centrifugal governing.

Tenth.—The compounding of the centrifugal and the load-governing forces to be effected in such a way that they shall operate upon the valve independently of each other, or more or less dependently.

In discussing Mr. F. H. Ball's paper before this society on the new principle in steam-engine governing, Mr. W. C. Kerr* states the primary requirements of an engine governor to be: (1) A reasonably small variation in speed, light or loaded; (2) a very small acceleration for an instant, following a change of load; and where the most delicate regulation is required, this instantaneous acceleration is of much greater consequence than the difference in revolutions between light and loaded conditions.

* *Transactions* of the American Society of Mechanical Engineers, Vol. IX., 1887–88, pp. 315, 316.

A compound automatic cut-off valve mechanism, operated by centrifugal and load governing forces, presents a somewhat satisfactory solution of almost all of these questions. Consider the case of a single valve for a single cylinder engine. The two governing forces may be introduced by making the valve of the piston type, and giving it a variable movement of reciprocation, with a variable movement of rotation or of oscillation, the movements being independent of each other. The valve friction will be reduced to a minimum by combining reciprocation with rotation. The centrifugal-governing forces control the variable reciprocation; the load-governing forces, the variable rotary movement, or *vice versa*.

An electro-magnetic mechanism under control of the turning moment of the dynamo, or its external electrical circuit, or of a circuit controlled by the variable load at a distant point, introduces the load, or dynamometric principle. This electro-magnetic control of the point of cut-off not only possesses great facility of application, but differs from all other applications of the dynamometric principle in not requiring intermediate transmissive mechanism, with gear-wheel or pulley trains, nor weights, springs, or belt tension devices of ordinary transmission dynamometers. It also acts instantaneously upon any change of load on the dynamo or other electrical circuit; and, it is not possible to anticipate further any load changes, because the slightest change of load is instantly felt at the valve, through the electro-magnetic mechanism controlling one of its movements.

An analysis of some of the combinations more or less desirable, as to the steam supply, gives to the reciprocating movement the main control, and to the rotary movement the auxiliary or independent cut-off, or *vice versa*. Both rotary and reciprocating movements may be operated independently or in conjunction with each other. In a single rotary-piston valve all the points of the steam stroke are under control. Arranged for the Corliss type, the rotary-piston valves would be used at each end of the cylinder to control the admission and cut-off, while release and compression are fixed for the best normal working conditions. In multiple-expansion engines, each cylinder is fitted with a rotary-piston valve; though, in some cases, load-governing forces may alone be used to control the steam supply for the low-pressure cylinder.

The piston valve placed vertically in the vertical inverted marine type of engines, reduces valve friction to a minimum, when

it is rotated and reciprocated, each to a continuously varying extent. Variable steam admission and cut-off is effected by helical or other curved ports in the piston valve and its seat. The two elements of the helical port may be designed independently or otherwise, according to the conditions under which the valve is to operate. The valve will thus have large port opening when most needed, and quick cutting-off qualities.

A compound movement of the stem of the rotary-piston valve may be accomplished, for instance, by giving the centrifugal shaft governor control of the reciprocation; and the electro-magnetic mechanism control of the rotary movement, by and through a turning sleeve (as a guide block) fitted over a squared portion of the reciprocating valve stem. Many other simple devices, to get this compound variable helical motion of the valve, will suggest themselves as circumstances arise.

The mechanism for both variable reciprocation and rotation may be any one of the many well-known forms; such as the pendulum, or the compound eccentric, for reciprocation; and quick-return-motion mechanism of the Whitworth or other types, for rotation. Or, mechanical combinations may be replaced by their kinematical equivalents in the form of electro-magnetic mechanisms. The peculiar advantage of the latter in this case is, that the variable electro-magnetic forces, under control of the dynamo or other electrically transmitted load variations, may be applied directly to the valve stem at the most convenient point, and without any reducing or other intermediate mechanism of a mechanical nature. This will also reduce the friction in the governing mechanism.

The electro-magnetic mechanism employed to control the valve movement, more or less in proportion to the external load, may be of several typical forms, utilizing different principles in the operation of electro-magnetic machinery.* The solenoid mechanism, for reciprocating rectilinear or curvilinear movement, having its coils connected in electrical circuit with the dynamo, and its iron core plunger connected to the valve mechanism; the armature mechanism, for partial or complete rotatory movement, whose small shaft is the valve stem, which is thus brought under electrical control of the

*See notes on Electro-Magnetic Machinery, *Journal of the Franklin Institute*, February and March, 1892, being reprints of two papers read by the author before the Electrical Section of the Franklin Institute, December 1, 1891, and January 5, 1892.

dynamo current; and an armature mechanism utilizing a proportional part of the turning moment (torque) of the main dynamo which is directly coupled to the engine (or may be otherwise driven) —these are some of the combinations desirable. In fact, these are sliding or turning pairs, under direct electro-magnetic control of the dynamo or other external load, and which may be used with the complementary movement from the centrifugal governor mechanism to produce the resultant variable helical movement of the rotary-piston valve, and so control the steam supply.

The fundamental principle of a rotary-piston valve makes it possible to apply it to other cases than that here considered especially. It admits of controlling the point of cut-off by hand, with reversibility, as in the Stephenson and other link motions, for which it may be substituted, so adapting it to the locomotive and marine service, where no special uniformity of speed is called for. A hand-wheel on the valve stem, or connected by suitable mechanism, would give absolute control of the steam supply and point of cut-off in these engines, whose eccentrics are fixed (of constant eccentricity). The reciprocations are made by a fixed eccentric, in the "Trenton" steam engine, built by the Phœnix Iron Company; and here the partial rotation of the piston valve is controlled by the centrifugal shaft governor, or by the tripping mechanism and dash-pot accompaniment of a fly-ball governor of the Corliss type.

On the other hand, the rotary movement may be made the chief element of the valve motion, and the reciprocation controlled by hand, by an auxiliary device. One rotary-piston valve may thus perform all the functions of an independent cut-off, as in the Buckeye and Meyer types, whether reciprocation or rotation be the chief element of its motion. In the latter, too, the rotary movement may be a partial or complete rotation, and either of these uniform or variable.

The rotary-piston valve, with its variable compound helical motion, possesses all the advantages of a slide valve and a piston valve, and the inherent disadvantages of neither. There is no scoring or grooving of the valve face or its seat, hence minimum liability to leakage and a maximum duration of normal working conditions. The structural advantages of piston valves are all maintained. By giving a rotary motion to a piston valve, or a sliding motion to a rotary valve, as is here done, the governing forces are a minimum to effect any change in either motion of the valve; for the

angular movement is more easily varied than it would be with no sliding, and the travel of the valve is more easily changed than with no rotation. These features make it very easy to control one or the other movements entirely by hand (in locomotive and marine engines), or by the sensitive governing mechanism referred to; and in the latter case this becomes a marked advantage, as it allows of dynamometric governing by delicate adjustments of the electro-magnetic mechanism to suit the external load conditions.

The advantages of governing steam engines by compounding the centrifugal and the load-governing forces, as by a rotary-piston valve, may be thus summed up:

First.—Best combination of conditions for uniform speed under no load or extreme variations of load, and steam pressure constant or slightly variable.

Second.—Steam supply as directly and instantaneously proportioned to the external load as it is possible to make it by electro-magnetically controlling the point of cut-off.

Third.—Valve friction reduced to a minimum.

Fourth.—Load-governing forces capable of the most sensitive and delicate adjustment by electrical means.

Fifth.—Independent governing against variations in the external load, compared with variations of driving effort and of the internal load of the engine.

Sixth.—Each governing principle regulates that which the other cannot, and without interference.

Seventh.—Rotary-piston valve, with helical ports, gives quick and sharp cut-off, with increased port area.

Eighth.—Failure of either governing device permits of the engine running temporarily under control of the other.

Ninth.—Dynamometric governing of central station multiple-expansion engines driving several dynamos, any one of which may be thrown on or off at any time.

STEVENS INSTITUTE OF TECHNOLOGY.*

IF any one should turn back to the volumes of the *Scientific American*, between 1871 and 1873, they would find various notices of the Stevens Institute of Technology, then being established in Hoboken, New Jersey, in which we took a lively interest, as being the first institution devoted exclusively to the training of mechanical engineers in this country, and, we may indeed say, in the world, if we take account of the special combination of theory and practice involved in its course of instruction; because in no school before had there been any such combination of the theoretical development of the science of mechanical engineering on a mathematical basis, with the practice of the same science as carried out in the foundries and workshops.

We naturally looked upon the experiment then and there inaugurated with the deepest interest and most cordial sympathy, because we saw how important to the prosperity of those mechanical industries on which our National prosperity rests, would be the success of this undertaking, which aimed at nothing less than the education of young men in a way that would fit them to go into the workshops of the country and supply the much-needed theoretical knowledge derived from the recorded experience of others with the aid of the potent tools of mathematical methods and practical familiarity with the machines and processes to be handled.

The two factors supplied for the solution of this problem were: A bequest of money and ground, amounting in all to about $750,000, made by Mr. Edwin A. Stevens, and a Faculty of young and energetic professors, headed by President Henry Morton, who had already distinguished themselves in their various departments.

It is now 21 years since this experiment was begun, and as we look at its results to-day we see our brightest anticipations and most sanguine hopes more than realized.

Graduates of the Stevens Institute are filling positions of the greatest responsibility in the workshops and great industrial enter-

* From the *Scientific American* of June 18, 1892, the title page of which was filled with illustrations of the Institute and several of its departments.

prises of the country, and are in demand beyond the capacity of the Institute to supply them, and, on the other hand, applicants for admission have for several years so much exceeded the capacity of the Institute to accommodate them that considerable numbers have been refused admission, not for lack of adequate preparation (though the scholastic standard has been constantly raised), but because there was absolutely no room to hold them.

When we compare the means available with the work done, we are astonished at the result from a financial standpoint.

It must be remembered that never in the history of the world has an institution of the higher education, and especially one for industrial training, where extensive workshops and laboratories have to be provided and kept running, been self-supporting. In all cases, large subsidies from governments or large endowments from private individuals have been required to support such establishments, and that the Stevens Institute should have reached its present dimensions and completeness with a building fund of but $150,000, and an annual income derived from less than $500,000 endowment fund, is simply marvelous in the eyes of any one familiar with the work and means of other institutions in this and other countries.

To be sure, some help, timely, if relatively small, has been supplied by President Morton, who, in the words of Mr. Edward B. Wall, M. E., President of the Alumni Association, in a recent address, "has devoted to Stevens his ability, his energy, his time, his tact and his private fortune;" but for such a work as this an amount of between $40,000 and $50,000 is but a trifling element, except as it may have supplied a great need at a critical time, as when he fitted up and presented the new workshop in 1880, established the Department of Applied Electricity in 1883, and endowed a Chair of Engineering Practice in 1888.

The fact still remains that the great success of the Stevens Institute has placed it in the position of a business which has outgrown its plant, and which must refuse orders for lack of capacity to fill them promptly.

With a manufacturing establishment the remedy would be simple, because such an increase in business would warrant an increase in capital invested, which could be secured in the usual ways. But with an educational institution the case is different. Here there is no increase in earning capacity which will pay interest

on the increased investment. On the contrary, as each student costs more than he can, as a rule, afford to pay, an increase in the number taught calls for an increase in the endowment fund, or its equivalent.

Realizing this situation the Alumni of the Stevens Institute have taken in hand the raising of an additional endowment fund, which may be used in the erection of new buildings, or otherwise go to the permanent support of the Institution.

In this work we wish them all success, and are free to say that we know of no place where one or more of those liberal donations, which have distinguished this era and this country, would do more good to the community at large, and be a more lasting and creditable monument to the donor, than the Stevens Institute of Technology.

In this connection we may say that we know personally that the name of any donor would be permanently associated with any department, building, chair, or scholarship, which he might endow or present.

COMMENCEMENT WEEK.

THE Commencement Week exercises began, as usual, with the Baccalaureate Sermon, which was preached by the Rev. George C. Houghton at Trinity Church, Washington and Seventh Streets, Hoboken, on Sunday, June 19. The services began at 10:45 A. M., and many members of the graduating class, together with under-classmen and friends of the students, listened with attention to the preacher's remarks, which were founded on the text: "Quit you like men; be strong," taken from St. Paul's First Epistle to the Corinthians, XVI. Chapter, 13th verse. The theme was appropriate, and was handled in an able manner, the sermon being one of the best that Mr. Houghton has delivered on many similar occasions.

THE RHO CHAPTER of the Delta Tau Delta Fraternity gave a tea on Monday afternoon, June 20, at their house on Bloomfield

Street. A great many ladies from out of town and from Hoboken were there, besides men from the different classes in the Institute.

CREMATION OF CALCULUS.—This entertaining ceremony took place Monday evening, in the presence of a great multitude, gathered together from all parts of the city. The students began to assemble on the Campus before 8 o'clock, and not very long after that hour the procession started. The men were arrayed in gorgeous costumes: Knights in coats of mail, Indians with dancing plumes, priests in long black robes, and darkies in most approved minstrel suits. Many of the boys, however, clung to the good old-fashioned *robes de nuit*, plentifully besprinkled with cabalistic characters, crowning this attire with battered high hats. These last-named costumes were most appropriate for the occasion, and the wearers of them had no fear of fire or water or "fire-water," while the birds in gay feathers had constantly to consider their plumage, and were restrained from enjoying the festivities to the utmost.

The line of march ran through some of the principal streets, and on the return to the Campus the trial of Calculus was begun without delay. Needless to say, the criminal was convicted in short order, without a show of mercy, and in a few moments the execution took place. The body was soon cut down and consigned to the flames, and then the boys celebrated their triumph by having a great war-dance about the bonfire. The Class of '94 had special charge of the celebration, but the other classes assisted with might and main. The official programme of the ceremonies was as follows:

Grand Marshal.

ROBERT E. HALL, '94.

Deputy Marshals.

F. J. ANGELL, '94, J. W. GILMORE, '94.

Marshals.

'92.	'93.	'95.
H. C. MEYER, Jr.,	A. E. MERKEL,	R. P. WALKER,
N. S. HILL,	H. F. CUNTZ,	E. HUTCHINSON.

Priests.

'92.	'93.
K. L. MARTIN,	W. P. MACKENZIE,
H. D. WHITCOMB,	M. E. CRAFT,
L. F. WETTLAUFER.	J. V. MACDONALD.

ORDER OF MARCH.

Grand Marshal.
Band and Drum Corps.
Horse Guards.
Foot Guard of Soldiers leading the Fiend and his Imps.
Priests, Vassals,
Indians, etc.
Symbols and Weapons of the Victim.
Class of Ninety-Two.
Chariot.
Class of Ninety-Three.
The Book.
Class of Ninety-Five.
The Preps.

CLASS DAY EXERCISES OF '92.—The most picturesque celebration of Commencement Week was held on the most charming spot about New York, the heights of Castle Point, on Tuesday afternoon at 4 o'clock.

The seats for the spectators were arranged on the lawn, in the shade of the old English elms, facing the Castle. In the distance were lovely views up and down the river, and near by the gay gowns of the girls caught the eye, and added brightness and color to the scene. After the Seniors had arranged themselves in the foreground, the members of the Glee Club came walking up two by two, accompanied by the strains of their own music, the "Singer's March."

Then the '92 Class Secretary, Mr. Henry D. Whitcomb, Jr., called the roll, giving each man his nickname, and sometimes two or three of them. The President, Mr. Howard F. Gurney, delivered some appropriate remarks, and introduced Mr. Henry C. Meyer, Jr., who made the presentation speech, calling the Seniors up in

turn, so that the audience might have a good look at them while he described their peculiarities. In this trying position the '92 men bore up bravely through all the laughter and applause of their friends and acquaintances. One young man, in particular, had the attention of the spectators drawn to the size of his nether extremities, and at the conclusion of the speaker's remarks was seized by two athletic classmates and held up in the air, with the soles of his shoes pointed directly at the audience. Fortunately for him, his feet were encased in elegant "patent leathers," and the girls did not think that the orator's words were entirely justifiable.

Several of the boys received "valuable" presents, including among other things a little wooden horse, "to be taken home to the children," a "punkin pie" for the man from the land of wooden nutmegs, and a bunch of flowers, tied by a ribbon whose color was strangely near that of a sash worn by one of the young ladies close by, which went to a young man whose modesty was equaled only by his blushes.

The banjoists and guitarists played well, as always, and were as warmly received, and as reluctantly allowed to depart.

Mr. Frederick H. McGahie delivered the Class Prophecy, in verse, telling of the fortune and fame which awaited the men of '92, occasionally giving a comical view of their destinies, and all the people re-echoed his wish that success might attend the Seniors and crown their efforts.

The Glee Club stood up, and the soft sounds of "Rare Ben" Jonson's sweet "Song to Celia," "Drink to Me only with Thine Eyes," were wafted through the air, carrying the listeners' thoughts backward through the centuries to the old English poet and lover. These tender reflections were soon interrupted by some rattling college songs and every one's thoughts took a more lively turn. Finally, the ceremonies were brought to an appropriate ending by a great cheer for Stevens and the Class of '92.

The charming custom of ha
this time, after a sleep of se

fortune to attend the exercises at Castle Point hope most sincerely that the coming classes may never forget to follow the bright example set by '92.

THE BOARD OF TRUSTEES held a meeting on Tuesday evening and transacted much important business, but as most of it was spoken of at the Alumni meeting, it need not be related here.

PRESIDENT AND MRS. MORTON gave their customary reception to the Faculty, the Alumni and the Undergraduates on Wednesday afternoon, June 22, and as usual it was well attended, and thoroughly enjoyed by all who partook of the hospitality of the host and hostess.

THE ALUMNI MEETING took place on Wednesday evening, but as its proceedings are fully set forth in another place, nothing need be said of it here.

THE JUNIOR BALL, given by the Class of '93 in honor of the Class of '92, was held at the Lenox Lyceum, Madison Avenue and Fifty-ninth Street, New York City, on Wednesday evening, June 22, at 9:30 o'clock.

The patronesses were:

Mrs. Henry Morton, Mrs. Edwin A. Stevens, Mrs. C. F. Kroeh, Mrs. E. P. C. Lewis, Mrs. A. R. Leeds, Mrs. G. F. Hall, Mrs. C. W. MacCord, Mrs. S. Bayard Dod, Mrs. T. B. Stillman, Mrs. S. S. Thompson, Mrs. Thomas Miller, Mrs. Andrew J. Post, Mrs. David A. Boody, Mrs. Nicholas S. Hill, Mrs. W. B. Litchfield, Mrs. M. D. Baillière, Mrs. E. R. Craft, Mrs. D. L. Braine, Mrs. R. Macdonald, Mrs. George H. Cook, Mrs. J. L. Furman, Mrs. W. A. Field, Mrs. G. B. Fielder, Mrs. J. C. G. Hüpfel, Mrs. H. D. MacGowan, Mrs. W. N. Griswold and Mrs. John McGahie.

The ball was a thorough success from every point of view. There was plenty of room for dancing, as the hall is so very large, the weather was reasonably cool, the music good, and all who were

there had a delightful time. The ladies sat in the boxes during the intervals between the dances, and supper was served at small tables.

The committee from the Class of '93 having the matter in charge, and to whose efforts the success of the evening is largely due, consisted of: A. V. Boody, Chairman; M. E. Craft, B. G. Braine, E. A. Huppertz, G. L. Wall, F. D. Furman and H. E. Griswold.

THE BASE-BALL GAME.—In spite of a light fall of rain, the annual base-ball game between the Alumni and the Undergraduates was played at the Cricket Grounds, on the morning of Thursday, June 23. The Alumni made great efforts and put up a strong game, but were finally overcome by the superior training of the college boys.

The score by innings was as follows :

	1	2	3	4	5	6	7	8	9	
Alumni.....	2	0	0	1	2	0	0	0	0—	5
Undergraduates..	3	6	0	3	1	0	0	0	1—	14

The complete score is given below :

ALUMNI.	A. B.	R.	1 B.	S. H.	P. O.	A.	E.
Rea, '84, 1 b.....	3	1	1	0	7	0	0
Wright, '83, s. s.....	4	0	0	0	5	1	2
Adriance, '85, 3 b.....	4	1	0	0	3	2	2
McBurney, '89, c.....	5	1	2	0	5	0	0
Sevenoak, (S. S.) l. f.....	3	1	0	0	0	0	0
Denton, '75, 2 b.....	5	0	1	0	7	1	3
McNaughton, '83, p.....	4	0	0	0	0	1	0
Hart, '87, c., c. f.....	4	1	0	0	0	0	0
Whitlock, '82, r. f.....	2	0	0	0	0	0	1
Carniaux, p.....	2	0	0	0	0	3	0
Riesenberger, '76, c. f.....	0	0	0	0	0	0	0
	36	5	5	0	27	8	8

Earned runs, 2; two-base hits, 2; passed balls, 4; wild pitches, 1; bases on balls, 5; bases on hit by pitched balls, 2; struck out, 8; left on bases, 4; time, 2 hours.

UNDERGRADUATES.	A. B.	R.	1 B.	S. H.	P. O.	A.	E.
Cuming, '95, c	3	3	1	0	8	2	0
Paulsen, '93, 2 b	5	2	0	0	2	1	0
Strong, '92, p	5	2	2	0	0	5	2
Inglis, '93, s. s	5	1	0	0	1	1	3
Schalk, '95, 3 b	5	2	1	0	3	1	1
Mackenzie, '93, r. f	5	1	1	0	0	0	0
Decker, '95, 1 b	4	2	1	0	11	0	0
Scott, '96, l. f	5	0	1	0	2	0	0
Shiebler, '92, c f	4	1	0	0	0	0	1
	41	14	7	0	27	10	7

Earned runs, 3; passed balls, 2; bases on balls, 5; bases on hit by pitched balls, 1; struck out, 7; left on bases, 3; double plays, 1.

THE COMMENCEMENT EXERCISES proper were held on Thursday, evening, June 23, but as a full account of them is given elsewhere, they will not be enlarged upon in this place.

THE QUINQUENNIAL REUNION of the Class of '87 took place at the "Arena," Thirty-first Street, near Broadway, New York City, on Saturday evening, June 25. In the first place, a business meeting was held, at which Mr. Franklin Moeller, the outgoing President, delivered an appropriate address, and Mr. J. A. McElroy, the retiring Secretary and Treasurer, made a report.

Mr. William E. Quimby was then elected President for the ensuing term, and Mr. J. Day Flack was elected Secretary and Treasurer.

Then came the banquet. Out of a class of thirty, sixteen were seated about the table, those present being: Robert M. Anderson, Robert N. Bayles, J. Calisch, J. L. Cox, J. H. Cuntz, J. Day Flack, B. F. Hart, Jr., E. H. Kiernan, J. A. McElroy, S. W. Miller, Franklin Moeller, W. E. Parsons, William E. Quimby, Alfred H. Schlesinger, Lemuel William Serrell and Herbert A. Wagner.

After an excellent repast had been disposed of, Mr. Quimby, the toast-master, made some suitable remarks, and then called upon Mr. Moeller, who responded to the toast of "The Class of '87." Mr. Flack spoke for the married men, fourteen of the class having

entered into the blessed estate of matrimony, while Mr. Kiernan pleaded the cause of the bachelors, who are still in a small majority. Later in the evening Mr. Cox related some of his experiences at the Midvale Steel Works.

Mr. Will Lyle entertained the class very much with his banjo playing, songs and recitations, and he and Mr. Hart sang some duets and held amusing dialogues. Mr. Schlesinger whistled in his old style, and the whole class joined in several songs. Altogether, a very agreeable evening was spent.

The night before, Friday, several members of the Class of '87 went to the Garden Theatre, New York, and attended the performance of "Robin Hood."

Strangely enough, in spite of the many married men, there was no claimant for the class cup, which will have to remain without an owner for another year.

THE COMMENCEMENT EXERCISES.

THE graduating exercises of the Class of '92 were held in Jacob's Hoboken Theatre, on Thursday, June 23, at 8 o'clock in the evening.

As the Trustees, Faculty and graduates walked slowly onto the stage the orchestra played an overture, and, when all was quiet again, prayer was offered by the Rev. Edward Wall, after which President Morton made the following introductory remarks:

Ladies and Gentlemen: Our Commencements recur year after year until they become a matter of course, and we cease to realize their actual significance. They are, however, very serious things if we realize their true character.

Not long since I was present on the occasion of the launching of an iron steamer.

Thousands were assembled to watch that one hull leave the cradle in which she had been formed and fashioned, braced and riveted, made strong to withstand the buffeting of the waves and to make her way through calm and storm, under the glow of the sun and the gloom of the night.

Ringing cheers hailed her entrance into the element in which she was to do her life-work, and many and hearty were the good wishes entertained and expressed, and as I watched the scene I thought how great was the responsibility of all concerned in the building of such a structure, upon whose soundness and integrity in every part might depend the fortunes and lives of thousands.

But here and in this hour we are witnessing the launch, not of one, but of thirty-nine, of the engineering "craft" on the ocean, not of water, but of life, freighted with hopes and ambitions of a high order, braced and timbered with solid knowledge, riveted with laborious strokes of study, and modeled on the best examples of the past.

Upon the soundness of their preparation and the integrity of their mental and moral structure may depend the prosperity of hundreds, nay, of thousands, or even of a nation, for a Stevens graduate may well reach such a position of responsibility that issues of the most momentous character may hang upon his decision. Seeing that it is the launching of such ships upon the sea of life that we are assembled to witness, we may well look upon the present occasion as a solemn as well as a joyful one, and appropriately open our exercises with a prayer and close them with a benediction.

The orchestra played "The Tyrolean," and then William Orr Ludlow delivered the Salutatory Address, as follows:

Mr. President, Trustees and Faculty—Friends: The Class of '92 greets you, and extends its most hearty welcome. We wish to express our appreciation of your presence with us this evening, for there is nothing more grateful than the interest and sympathy of friends.

And especially on this occasion do we welcome you, for to night is a turning point in the life of each one of us, and it is at such a time that the grasp of the hand of friendship is particularly gratifying and encouraging.

Our four years of study at Stevens have passed, and as we look back upon them they seem a bright dream, from which we now

awaken to face the serious realities of life. And as we stand before you, perhaps one of the most natural questions to arise in your minds is: "Well, and what have you learned?" I imagine that many of you think that our training has been in one limited field; like the microscope, which enlarges a hundred fold the area directly under its lens, but leaves the rest of the object almost undiscovered.

First and foremost, we have learned all that the leading Institute of Technology can teach, in four years, in regard to mechanical engineering; and I might go on and tell you how we have laid the foundation of principles, and how we have striven to blend theory and practice, but I venture to say that there is not a man in the class before you who has not rehearsed these things so often that both to him and his friends it is an old story.

Then, have we learned anything beyond the technical work of engineering?

I am going to speak first of one or two things which we have not learned, not to inform my audience, for that is unnecessary, but simply to instance some of the mistaken ideas which have been entertained by others who know less about Stevens Institute.

A '92 man, upon informing a friend that he had learned blacksmithing, was asked in a very incredulous tone, if we had "real horses to shoe at Stevens." No, was the reply, we have no real horses, but there have been animals here which closely resemble horses, except for tail and ears. They don't stay long with us; they try elsewhere.

And there have been more than one whose ideas have been even more erroneous than this. They imagine that after the young man has spent four years in studying the abstract and abstruse principles of higher mathematics, and after mastering with exceeding difficulty the subjects of kinematics and thermodynamics, that he graduates to take his seat upon the engine-driver's bench in the locomotive cab, to open the throttle and blow the whistle.

All such misconceptions were quickly dispelled from our minds before we had been inside those old gray walls many days, for we were informed most emphatically by one of our worthy professors that an engine-driver is not an engineer. It is half the battle of a student's life to learn how to study, to learn how to apply his mind, how to select the essential points of a subject that he may use them as the warp upon which to weave the fabric of the whole matter, and it is certain that the survivors of this four years' conflict must have

learned these things, else they would long ago have been among the killed and wounded, who have fallen from our ranks with the regularity of recurring examinations.

Could we have worked a year in the physical laboratory, under the head of that department, having it as an ordinary duty to measure the one-ten-thousandth of an inch, and not learned what is so essential to an engineer's work, exactness and precision?

Could we have spent months in the shop, among whirring wheels, learning to handle all kinds of machinery, without finding out, often by bitter experience, what carefulness and presence of mind mean?

Could we have solved some of the intricate problems of calculus, resistance of materials and applied mechanics, without receiving such a training in patience and perseverance, as is seldom acquired?

We came to Stevens to learn how to work, and we came to learn why and how things in the mechanical world are as they are.

It is related of an engineer that he was once called upon to start an engine, which could not be made to run. He looked it over carefully, then picking up a hammer he struck a certain part a sharp blow. The engine started and ran without further difficulty. Upon sending in his bill for $25, the engineer was remonstrated with for demanding so large a sum for so little work. Accordingly, he returned an itemized bill, which read as follows:

"Twenty-five cents for starting engine, $24.75 for *knowing how*."

It is not merely the ability to strike the blow, that we learn at Stevens, but it is the knowing how.

And now our training is over; we are about to cross the threshold of our old place of preparation, to step out into the wider world. And as each '92 man looks across that promising but indistinct landscape of the future, this question is uppermost in his mind: "Is my life to be a success?" Do we wish to succeed, let us determine that we will succeed; but we must remember that whatever we attain in life will be only through our own efforts.

The men who hold the positions of trust and responsibility in the world to-day, are men who have made themselves capable of so doing, by their energy, and by their industry.

And so with one look back at the bright days of old, and with one look forward into the uncertain days of the future, with the deep feeling of sorrow that must come, when the ties of strong friendship are broken, and the determination that whatever pluck,

ambition and perseverance can bring us, shall be ours, we step forward to assume the duties of our lives.

The Glee Club sang and gave an encore.

Alfred R. Wolff, '76, then addressed the graduating class in the following terms:

Mr. President, and Ladies and Gentlemen: Deeply conscious and appreciative of the honor of being the first Stevens man selected to address the graduating class of my Alma Mater, the choice, none the less, has been a source of great perplexity to me. Well I know the many Stevens men, who not only have had greater experience and stand higher in the profession, but who, besides, have the rare faculty of speech, the gift and the power to move souls, which is denied me. Indeed, frankly speaking, I had almost given up the problem, as we engineers are occasionally compelled for the time being to give up some engineering problems, when, of a sudden, the cause of my selection became plain to me. I remembered how frequently our esteemed Dr. Morton had caught my tired eyes and the half-restrained yawn at Commencements (not, of course at Stevens), when learned but lengthy addresses were being delivered, and how this recollection must have led him to say: "Well, Wolff has been such a sufferer; if I select him, he is sure not to inflict us with a long speech." And here our President again showed his noted perspicuity, for, ladies and gentlemen, I sympa, thize with you on this warm night. I know a good speech is all the better for being brief. I am certain the only thing which will condone a poor speech is its brevity. It is scarcely necessary to say any more by way of introduction and apology, except perhaps, being so near home and among friends, far removed from the turmoil of our great cities, let me whisper to you confidentially that I was born in Hoboken and received my entire education in the schools of Hoboken. I leave it to you, Mr. President, and ladies and gentlemen, could I put forward a stronger plea for indulgence and consideration?

Gentlemen of the Class of '92: It is fitting that a graduate of your Alma Mater should address you on this occasion, for no one can so thoroughly appreciate your feelings, your desires and your hopes at this time, as one "who has been there himself." I know what this hour means to you. I know the rare opportunities you have enjoyed, the "experimental" and "thermodynamic" struggles you

have overcome, and I know, above all, that the passport of your professors is a proof that you are as well, if not better prepared in engineering equipment, in manhood and in honor to cope with the vicissitudes of the engineer's career, as is the product of any other school of engineering in the world. Rare advantage to have been four years under the fostering care of such disinterested, courageous and talented scientists and pedagogues as form the teaching staff of Stevens, men who live for their work, without a selfish thought, except to advance the interests of their departments, their specialties, and, above all, the education of the young men in their charge. What technical training within college halls can convey has been given you, and now it is experience in practical life, which no college can impart, which must do the rest. The world lies before you, and you must find your place and do your work in it. Standing, as you do, on the threshold of a new life, it is my pleasant duty, aye my privilege, to welcome you within our ranks, to bid you God-speed, and to say a few words of encouragement and advice.

It were easier to discuss with you some weighty technical question, or the general aims which distinguish our profession, but I consider a homelier topic of more timely importance—viz :

"SOME MORAL FACTORS IN THE ENGINEER'S CAREER."

What we are all after is success. Each engineer, were his ambitions realized, would be the foremost in rank, do great things, gain fame, position, power, and possibly wealth. I say *possibly* wealth, for, gentlemen, you may as well understand clearly at the outset that the financial return of the engineer's work is, as a rule, not large. It is difficult to obtain statistics, but it takes no great powers of observation to note that a given amount of energy and ability meets less money award at the present time in engineering than in the professions of law and medicine. Despite the rigid teachings of political economy to the contrary, expressed in the laws of demand and supply, I have been inclined to believe that the fault lies, to some extent at least, with the engineers themselves, inasmuch as they do not raise the standard of fees and compensation along the whole line. But whatever the cause, the fact is as stated, and one to be deplored. Remember, however, that the very best way to defeat the ultimate securing of proper financial return is for young men to practice the profession with that aim solely, or even mainly, in view. And this brings me to my first point of advice : Whatever

you undertake in the beginning, for a few years at least, let the money consideration be of slight import. Accept such positions as give you an opportunity for acquiring further knowledge, for gaining the right kind of experience and judgment—positions in which you have an opportunity to wipe out the special deficiencies you individually possess, and which deficiencies you yourselves best appreciate.

Judge impartially. One of you knows well that he is peculiarly weak in shop practice, another that he is a mere child in business thoughts and transactions, a third that design is his failing; if possible, let each secure a position, then, in which his special deficiency is eradicated, or, at least, partially cured. It is not for me to argue what particular work to take up first; circumstances and chance will decide this to a great extent, but in accepting positions on graduation be sure that the financial return is the subordinate and not the controlling motive. After a few years spent in this work of preparation you can take up your real activity in life; the indecision and lack of self-confidence, which prove such barriers in the beginning, will have vanished, and you will be in position to judge which specialty to follow. But, in the meantime, be not discouraged by rebuffs, and, in any event, do not remain idle long. If in position to do so take a vacation until the fall, but then start in earnestly for work. You need no further university career for the successful practice of your profession. European travel will be a more profitable investment three years hence than now.

After the preparatory work outlined, adopt and follow a specialty. Except for men of genius, success lies alone in this. Possibly a genius is among you. To him I do not speak. For it matters not what the course pursued, genius will win in the race. But most of us possess but average capacity, possibly talent, and we, the great majority, can achieve recognition only by cultivating assiduously and taking front rank in some specialty. The field of the engineer is so large that it is hopeless to till satisfactorily more than a small meadow, and it is only by concentration of effort in a special department that the flower of success is within reach. In selecting a specialty take into account not only your own limitations and your adaptations, but also whether the specialty has the chance of a material significance.

While, however, following and cultivating a specialty do not grow narrow. Keep posted generally about all the great advances

in engineering, and particularly in respect to the fundamental principles which underlie the progress. For this the successful pursuit of a specialty demands.

Be self-respecting, but modest. Each man, in his soul, best knows the real worth of his achievement. The world is ready to give credit, and without self-respect nothing can be accomplished. Still, we are apt, be it by the plaudits of our colleagues, be it by an apparent lack of appreciation on their part, to over-estimate our accomplishments and to grow conceited. The conceited man will not be the successful man. Conceit kills progress. A good way to prevent an over-estimation of our work is to ask ourselves, What does it represent when compared with the life-work of Coulomb, of Weisbach, of Rankine, of Holley, and of the many other bright stars of the engineering firmament. And if perchance Rankine does not put our achievement to the blush, then let us weigh it in the scale of the world's work in engineering as a whole.

Be honest! Does the suggestion seem an insult? Carefully trained as you have been, surely every thought and impulse removes you from doing aught but what is honorable. But the temptations in the practical pursuit of our profession are great, and many engineers, and among them, I fear, graduates of technical schools, who at this hour of their life stood as unsullied as you, have fallen. Therefore, my caution. The tempter is so ingenious, so insiduous. He crops up at every step, often in queer and almost complete disguise. Let me give you one illustration only where hundreds are at hand.

We are engaged by a client to write a specification and make plans on which general contractors will bid, and we are to superintend the work. Many machines must be specified. They have a staple market value, and whether we specify some devices or others, all equally good, and of the same cost, the work will not be affected either in value or in price, as far as the competing bidders or the client's purse are concerned. Along comes the salesman and offers us a commission, a bribe, if we will specify his devices. We remonstrate, are indignant, and order him out. He argues that his goods are sold for a standard price to the competing contractors, and that if we do not accept the commission he is simply so much in pocket. Or, we see nothing of him until after the contract is awarded. We have specified his machines because they are the best or most suit-

able, and after the award he calls on us, and urges us to accept a fee in recognition of our having specified his goods. Or, the general contractor, after award or completion of contract, desires to pay us a commission or a percentage of his profits. Every attempt is made to prove that our client gains nothing by our refusal, that we are fools not to accept the commission, and the monetary returns seem large and easy of attainment. Do not be deceived by the tricks of these philanthropists, who are so anxious to get rid of their money. Advise them to spend it on public charities instead. Drop them a hint that you well know their game. They wish you to see their machines and their work, if not on this special contract, then, on the next, through the refracting medium of the dollar bill, obscuring your vision and biasing your judgment. Let your conscience not falter for a single moment. I may take an extreme view, but it is my firm belief, and I consider it a privilege to say it here, on this occasion publicly, that the engineer who receives a commission in this way is a thief, unknown to his client and the law, but to his own knowledge a convicted criminal in the power and under the final and absolute command of the party who has purchased him. To the engineer who does not practice his profession with unswerving integrity, success is impossible. It may seem for a short time to be at his door, but it will soon vanish. Aye! Were engineering success thus attained, believe me, it were but a curse.

My next point, gentlemen, is: Do all in your power, make use of your leisure, to gain wide culture and foster broad interests outside of the engineering profession itself. In the past, the general standing of the engineer and his work have suffered somewhat because his interests have been centered too exclusively on his professional labors. We must be glad and able to meet men of affairs and of other professions on the common ground of culture, of literary attainments and social amenities, which add grace, dignity and unity to life's intercourse. Thus alone can the engineer gain the social distinction which is his due, and social position of the right kind is an important factor in success, and within proper limits, lends dignity to the profession and its devotees.

Be good citizens! Take an active interest in movements which tend to humanitarian, social and political advance, for this is a duty, which both as men and as engineers, you owe mankind and the State. Were this participation more general, I doubt not, all

public administrative offices, involving large engineering interests, would have as their heads, engineers, instead of, as is now the rule, politicians, in the restricted sense of the term, who harass and weaken the work of their engineering subordinates.

A good character is at the bottom, is the impregnable substructure of engineering success, as it is, indeed, of every other department of life's work. Preserve your good character and a clear conscience under all temptations. Be true to the teachings and aspirations of your Alma Mater. Thus, working faithfully, a measure of success is certain to come to you. We can not all be great engineers; we can all pursue useful and honorable careers. Stick steadfastly to the highest instincts and noblest aims of our profession, and well equipped as you leave the portals of Stevens, you can look forward hopefully, trustfully, to the future.

"Every day brings a ship
Every ship brings a word,
Well for those who have no fear
Looking seaward well assured
That the word the vessel brings
Is the word they wish to hear."

—*Emerson.*

May it be so with you!

The Banjo Cub played, and were received so heartily that they had to play again, and then a third time.

Mr. S. Bayard Dod, the President of the Board of Trustees, then arose and said:

The programme calls for the usual announcement of the name of the winner of the Priestly Prize; but this I cannot make. The prize is there, but there has been no contest; probably because the class has felt that it was not fair to put their professors to the mental strain of deciding who was first, where all were of so high a grade.

It is customary at these annual commencements for our colleges and universities to tell their friends and patrons what they have been doing in the past, and what they intend to do in the future.

It has not been the custom for Stevens to proclaim her doings with blare of trumpet or flare of torch, except when the men of Stevens are having their final dealings with the calculus. Then I believe they are liberal in the use of both horn and torch.

Nor has it been necessary to foster the growth of the Institute by any effort; the question with us is, not how to get students to come, but how to take care of those who crowd at our doors for admission.

It was easy to provide for the first class which graduated in 1873, for it was composed of only one man; it is harder to meet the requirements of the 120 men who will seek entrance to Stevens next fall. But the Trustees are planning to do this, and, with the help of our friends, they will do it. They propose to raise the roof of the extension on the north and add two stories to it, and so take care of the class that will come to us next fall. The Alumni have generously contributed $17,000 toward the new Chemical Laboratory, and, when the balance of $33,000 is subscribed, the Trustees will go on with that building; and so we shall be able to take care of future classes.

What we have done in the past assures us of the future. We have graduated nineteen classes of men who are able to take their places in the world with such credit to themselves and their Alma Mater that I have been repeatedly assured by men in management of large and important industrial works that they need no higher commendation of a man than the diploma from Stevens.

And now this twentieth class comes to us for their degrees, a solid phalanx of high standing, a class of thirty-nine without a single condition.

We want our friends to know that we are ready and anxious, if the means are placed in our hands, to give to all who ask it this thorough education.

And I have the pleasure of announcing that, at the recent meeting of the Trustees, President Morton presented to the Institute the sum of $20,000 for the further endowment of the Chair of Engineering Practice.

This is not the first of President Morton's gifts to the Institute. He gave $10,500 towards fitting up the workshop; $2,500 for the Department of Applied Electricity; $10,000 for the endowment of the Chair of Engineering Practice, and now this $20,000 to the same chair.

The sum total of these gifts amounts to nearly $50,000, and perchance, exceeds that sum, if we reckon the many smaller but constant gifts, not set down in the books, with which he tided over this or that minor dificiency in the various departments.

But generous as he has been with his gifts of money, he has given far more than these; he has given his brains, his heart, himself, to Stevens, with untiring devotion.

This is of ten times more value than all else, of a value indeed that cannot be measured by the lower standard of dollars and cents.

What Stevens is to-day she owes to Henry Morton. The course of education which is to be for you, young men, a priceless blessing through your life, you owe to him.

If I seem to violate the ancient maxim that it is not fitting to sacrifice to heroes until after sunset, my excuse is this: That, in the literal sense it is after sunset; but in the metaphorical sense I do not want to see the day when it shall be sunset for our honored President.

I know that I voice the sentiment of every loyal son of Stevens when I say, "Long live Stevens!" and long live Henry Morton, her first and foremost President!

Mr. Dod then conferred the degree of Mechanical Engineer upon the thirty-nine members of the Class of '92.

The list of the graduating class, together with the subjects of their respective theses, is as follows:

HAROLD B. ATKINS, JOHN T. SCHRAMME,
An Investigation of the Dynamic Field by Means of a Revolving Coil.

F. W. COHEN, WILLIAM C. CUNTZ,
Design of a Railroad Bridge of 243 Feet Span, Under the Greatest and Least Loading, According to the Practice of the Present Day.

LAWRENCE B. CORBETT, PIERSON L. WELLS,
Review of a Plant for the Manufacture of Wood Spirit and Acetate of Lime, at Galeton, Pa.

LUCAS FERNANDEZ, AUGUST R. HAKE, HAROLD HARRISON,
Review and Test of the Multiple Distribution System of an Electric Railway on Coney Island, at Brighton Beach.

FREDERICK GARDINER, HENRY W. JACKSON, EDWARD L. JONES,
Review of the Leonard System of Operating Electric Motors.

NICHOLAS S. HILL, JR., WILLIAM ORR LUDLOW, GEORGE H. MILLER,
Test of Double Screw Ferry Boat "Bremen" in Ferry Service.

HOWARD F. GURNEY, CARL H. HOTOPP, HORACE L. SHEPARD,
Test of the Electric Light Plant at the New Jersey Central Railroad Station, Jersey City.

HARRY DEG. KING, WILLIAM B. POWELL, ANDREW SHIEBLER,
Review and Experimental Test of the Steam Plant of the Steamship "Iroquois."

FRANK E. LAW, ELECTUS D. LITCHFIELD,
Test of the Electric Light Plant at the Delaware, Lackawanna and Western Railroad Station, at Hoboken.

HERMANN LOEWENHERZ, OSCAR C. WHITNEY,
An Experimental Determination of the Electrical Resistance of Twelve Different Fluids.

KINGSLEY L. MARTIN, FREDERICK H. MCGAHIE,
ARTHUR W. PATTERSON, JR.,
An Experimental Determination of the Action of and Results Produced in an Air Compressor, Compressing Air at High Tension.

HERBERT L. MERRICK, CHARLES F. VOGELIUS, LOUIS F. WETTLAUFER,
Test of Plant of Otis Elevators of North Hudson County Railway Company, at Weehawken, N. J.

HENRY C. MEYER, JR., HENRY D. WHITCOMB, JR.,
Review of Ventilating and Heating Plant of the Syms' Auditorium, at Fifty-eighth Street and Eighth Avenue, New York City.

JOHN H. MURRAY,
An Experimental Determination of the Efficiency of Tan for Fuel, at Proctor's Tannery, Jameson City, Pa.

ANDREW J. POST, JR., WILLIAM E. S. STRONG,
Review of a Whaleback Steamship, and Test of the Steam Plant on Same.

HARRY D. REED,
Insulation and Capacity of Electric Cables.

PHILIP VIDAL, F. LOUIS WAEFELAER, JR.,
Experimental Determination of the Quantity of Heat Produced by the Combustion of Different Fuels.

The orchestra played "Mathilde," from "Faust," and President Morton then remarked:

After what has been said by Mr. Dod I must, even at the risk of interrupting the regular programme, say a word in order to fill out a subject which his kind enthusiasm has caused him to overlook. I am ready to plead guilty to all he has charged me with so far as *intention* goes, but my best intentions and best efforts would have been powerless without the unremitted labor and loyal co-operation of the ablest Faculty ever assembled in any educational establishment in this or any other country.

It is to these men who sit around me to-night and to their combined genius and persevering effort during the past twenty-one years that Stevens owes her proud position, and her graduates their universal success in their profession.

Mr. Nicholas S. Hill, Jr., then delivered the Valedictory Address:

My Professors, our Trustees, Fellow Classmen, and Friends:— We are assembled to-night all from the same cause, the graduation of '92, but different motives arising from the common cause have called us here. Our Faculty to crown our labors with a certificate of our mental ability and conscientious work, we to receive this coveted prize for which we have striven during the last four years, our friends to show their satisfaction at our past success, to wish us success for the future and by their presence to let us see that they appreciate only too well what a momentous event in a man's life is the night that he steps from Seniority in a happy college world to verdant Freshmancy in the strife of life.

There are before me mothers, fathers and sisters, and perchance, some of the fair sex who take more than a passing interest in some member of my class; you all join in the pride we feel in accomplishing our first work, but mingled with that pride is a fear, a hope for the future. That unfathomable future looms up before you, you cannot separate the uncertainty of what is to come from the certainty of the past. What is in store for those whom you love? Is it success or failure, good fortune or disappointment, health or ill health, a long life or an early grave? Will my fellow classmen persevere? Will they not only make good engineers, but men, true to their country, true to their friends, and true to themselves? If we could unravel the thread of fate we might know, but

> Heaven from all creatures hides the book of fate,
> All but the page prescribed their present state.
> What future bliss you have not now to know,
> But you have hope to be your blessing now.

So you must hope, and my parting wish to you, dear mothers, is, that all your hopes may be fulfilled, may your boys by their career repay you for the sleepless nights you have spent for them, for the care you have exercised over them, and for the anxiety you feel for them to-night. May they all be good sons of good mothers, who, by their manly, straightforward course will bring solace and peace to the old age of their best friends.

My professors I would thank most heartily for their earnest work in our behalf. It is with but one unpleasant recollection that I leave them; it is to think how little I have ever known them. You, my preceptors, must realize how little intercourse there is between professor and student at Stevens. You know us, you judge us by our recitations and work. We judge you by your style of

teaching and methods in the class-room. Neither knows the motive which prompts the other. This snap judgment does not allow you to learn the real worth of many students, or the students to learn the really conscientious motives which prompt you. Of course, then, I cannot feel as deeply as I would like in leaving you. But I do go away with admiration and respect for you, with a desire that some day I may know you more intimately. Moreover, I feel that in any way you may try to improve our Alma Mater, '92 will be among your most ardent supporters, for I am sure my whole class join with me in the greatest confidence in your good judgment and learning. We depart, then, dear sirs, owing you a debt of gratitude for your patient guidance, knowing that if we are failures it is through no fault or lack of effort on your part, but by our own incapacity. May the results achieved by my class prove an ample reward to the noble profession you pursue, the education, enlightenment and expansion of young minds.

And now, my fellow classmates, the time has come when we, too, must part—the time when we can no longer work together for our class, but must each one of us, by our individual efforts, hold old '92's name still to the front. Our class has made its reputation in college; we must not give up now, but fight more strenuously than before to keep her foremost, as she was foremost in college. To do which, we must be men of patriotism, realizing that we are not alone engineers, but true American citizens born on free soil. Every one of us must lead a dual life, a private life under the shadow of our home and a public life under the ægis of the State. As a father, a husband or a son we owe certain duties to the family; as citizens we owe certain obligations to our country. These civic virtues are all comprised under the generic name, patriotism. Patriotism means love of country; our country is the common parent of us all. It is the paternal home extended, the family, reaching out to the city, the province or country.

Country and fatherland are, therefore, synonymous, and country in this sense comprises two elements, the soil itself and the people who live thereon. We love the soil in which our fathers sleep, the land in which we were born. We love the men who as fellow dwellers share that land with us. Let a citizen from Maine meet one from Oregon in the desert wastes of Africa or the crowded streets of London, they will at once forget that at home they lived three thousand miles apart. State lines are obliterated, party

differences are laid aside, religious animosities, if such existed, are extinguished. They warmly clasp hands, they remember only that they are fellow Americans, children of the same mother, fellow dwellers in the same land over which floats the star spangled banner.

Patriotism implies not only love of soil and of fellow citizens, but also and principally attachment to the laws, institutions and government of one's country; filial admiration of statesmen, heroes and men of genius who have contributed to its renown by the valor of their arms, the wisdom of their counsel or literary fame. It includes also an ardent zeal for the maintenance of those sacred principles that secure to the citizen freedom of conscience and an earnest determination to consecrate one's life, if necessary, in defense of fireside and home, of family and country.

Anyone, however lowly, may be a patriot; they may have that inherent love of country for sake of which they must be good. If you possess this love you will not only be true to your Nation, you will be lovable in your homes, sincere with your companions, conscientious in your profession.

I feel confident, my fellow classmen, you will be good citizens, and if you are, what a feeling will come over us when we meet, not only as true Americans, sharers of the same soil, but members of a noble profession, whose name we have kept untainted by corruption, sons of the same Alma Mater, brothers of the same class.

A thrill of pride runs through me, when I look forward to meeting you as men, who, by your broad views, liberality, education and honesty, will stand before the whole community an honor and distinction to your family and State. When viewed in this light the pain of our dissolution is lessened. I feel that the grief at this parting will be washed out a hundred times by the joy experienced in seeing success and integrity planted upon your familiar countenances at our class reunions.

And still one drear sensation haunts me, that whatever the joy in meeting you again, there may be some face wanting, some one called by his Creator to receive his retribution or reward. A sad thought, my friends, still, one we all must experience. But, fellow students, if we follow the dictates of conscience we shall meet hereafter; there will be no such word as farewell; we are simply branching out to follow our mission in life, to join once more, if not on earth, in eternity.

The Glee Club then sang, and sang so well that they had to sing several times again.

The Rev. George C. Houghton pronounced the benediction, and then the audience slowly dispersed while the orchestra played. Before leaving the stage the Class of '92 gave a loud cheer, and so ended their course as undergraduates at Stevens.

The '92 Commencement Committee was made up of: Electus Darwin Litchfield, William Orr Ludlow, Frank Everard Law, Lawrence B. Corbett, Carl H. Hotopp and William Edward S. Strong.

The Reception Committee from the Class of '93 consisted of: Bancroft G. Braine, Beattie A. Inglis, William Y. Dear, Percy W. Mackenzie, Mors O. Slocum and James V. Macdonald.

ANNUAL MEETING OF THE ALUMNI ASSOCIATION.

THE sixteenth annual meeting of the Alumni Association of Stevens Institute of Technology was held in the Hall of the Stevens School on Wednesday evening, June 22.

The President, Mr. Edward B. Wall, took the chair at 8:30 P. M.

The following persons were present:

Mr. and Mrs. S. B. Dod.
President Henry Morton.
Prof. C. W. MacCord.
Prof. Albert R. Leeds.
Prof. Charles F. Kroeh.
Prof. Edward Wall.
Prof. James E. Denton, '75.
G. C. Henning, '76.
William Kent, '76.
Philip E. Raqué, '76.
Prof. A. Riesenberger, '76.
Alfred P. Trautwein, '76.
Edward B. Wall, '76.
A. R. Wolff, '76.
Prof. Wm. E. Geyer, '77.
F. E. Idell, '77.
L. H. Nash, '77.
Henry K. Morrison, '86.
Edw. F. White, '80.
R. M. Anderson, '87.
J. Calisch, '87.
J. H. Cuntz, '87.
Joseph A. McElroy, '87.
W. E. Parsons, '87.
Alfred H. Schlesinger, '87.
Henry A. Bang, '88.
Richard Beyer, '88.
P. A. Doty, '88.
W. J. Beers, '89.
Paul C. A. Graupner, '89.
F. J. Gubelman, '89.
Nicolai H. Hiller, '89.
G. B. Muldaur, '89.
Robt. C. Oliphant, '89.

George M. Bond, '80.
Durand Woodman, '80.
A. C. Humphreys, '81.
Albert Spies, '81.
Jos. Wetzler, '82.
R. H. Whitlock, '82.
M. McNaughton, '83.
Ernest N. Wright, '83.
Prof. W. H. Bristol, '84.
Wm. L. Lyall, '84.
Henry R. Rea, '84.
Wm. A. Adriance, '85.
Wm. S. Corwin, '85.
Rollin Norris, '85.
C. R. Collins, '86
C. J. Field, '86.
George G. Plyer, '89.
Wm. B. Wreaks, '89.
D. C. Harvey, '90.
E. E. Hinkle, '90.
E. H. Peabody, '90.
E. H. Whitlock, '90.
Alex. Dow, '91.
L. E. Elson, '91.
John M. Hansen, '91.
Albert R. Mount, '91.
L. H. Nettleton, '91.
J. Arnold Norcross, '91.
W. C. Cuntz, '92.
Edward L. Jones, '92.
Henry D. Whitcomb, Jr., '92.
Oscar C. Whitney, '92.

The reading of the minutes of the last meeting was dispensed with, the same having been printed in the INDICATOR.

REPORTS OF COMMITTEES.

The President: Under the head of reports of committees, I call for the reading of the report of the committee of which Mr. Humphreys is Chairman, on procuring a portrait of President Morton.

Mr. Humphreys read the following report, which was on motion accepted and filed:

REPORT OF PRESIDENT MORTON PORTRAIT COMMITTEE.

This committee, in rendering its final report, wishes to say a word in explanation of the discrepancy between the amount estimated as needed and raised and the amount actually expended for the portrait.

When the scheme was first discussed, some inquiries were made, and, as a result, it was determined that to carry through the plan $1,000 at least would be required, and action was taken accordingly.

When President Morton was consulted, it was found that his preference was for a black-and-white portrait; he was also reluctant to have spent upon his portrait the amount named. The committee finally were convinced that President Morton's judgment as to the character of the portrait was correct, and through his co-

operation a portrait was obtained from an artist of his selecting at a minimum cost. It was then suggested that part of the money thus saved be used in preparing a little volume descriptive of President Morton's life's work, this volume to be distributed among the subscribers as a souvenir. This was done, and, as a result, the committee is prepared to distribute this evening to such of the subscribers as may be present this souvenir biography.

It will be remembered that it was originally arranged that any final balance remaining over should be left in the hands of President Morton, to be appropriated to some special Stevens work. At the winter meeting of the Alumni Association, President Morton announced that this balance should be placed to the credit of the Special Alumni Building Fund. The committee is now able to announce that there will remain in hand after settling the bills on account of souvenir volume a sum a little in excess of $500, and this amount will be placed in the hands of the Treasurer of the Building Fund.

The total amount subscribed was		$1,008.50
Saved on English Exchange		.03
		$1,008.53
Paid out for portrait and frame	$250.00	
" for stationery, postage and sundries	54.83	
" for souvenir	200.00	
Balance—to be placed in hands of Treasurer of Building Fund	$503.70	$1,008.53
Number of subscribers	193	

Respectfully submitted,

C. J. FIELD,
ALEX. C. HUMPHREYS,
ALFRED R. WOLFF,
GEO. M. BOND.

Mr. Humphreys: I would like to say a word about the distribution of the volumes referred to in the report. If subscribers who are present will present themselves immediately after this adjournment at the Treasurer's office, in the main building, we will give the volumes out at that time.

The Chairman: The next committee to report is the committee which is known as the Regular Portrait Committee, of which Mr. Spies is Chairman.

Mr. Spies: It may, perhaps, be well to explain again, although it is undoubtedly known to most of the members present, that a Special Portrait Committee was appointed by the Executive Committee two or three years ago, with a view to collecting funds and procuring portraits of a number of the prominent members of the engineering profession, these portraits to be presented to the Institute by the Alumni Association. Among the first portraits obtained was that of Ericsson, which was followed a short time after by that of Edwin A. Stevens, the founder of the Institute. The latest results achieved by the money accumulated by the committee are before you this evening in the two portraits presented, being those of Col. John Stevens, the father of Edwin A. Stevens, and of Robert L. Stevens, the brother of Edwin A. Stevens. The portraits, as you see them, are ready to be delivered to the Alumni Association, and to be by them presented to the Institute in the regular way. I might add, in this connection, that the procuring of those two portraits has about exhausted the available funds of the Portrait Committee, the sum total now remaining in the hands of the committee being $1.72. Under the circumstances it may not be amiss to direct attention to the fact that any subscriptions will be very gladly welcomed by the committee.

On motion the report of the committee was accepted and filed.

The President: The report of the Recording Secretary is now in order.

REPORT OF RECORDING SECRETARY.

At a meeting held December 19, 1891, the old Committee on Beneficiaries was continued in office.

At a meeting held December 19, 1891, the committee authorized the Treasurer to bear one-half the expense of preparing, and the total expense of framing the pictures, in black and white, of Col. John Stevens and of Robert L. Stevens, Messrs. Bristol and Spies being appointed a sub-committee. The pictures have been duly obtained, and have been presented this evening by the sub-committee.

At the meeting of December 19, 1891, the Executive Committee endorsed a circular drawn up by a special committee of Alumni, which circular related to the obtaining of subscriptions for the preparation of a portrait of President Morton. This portrait was duly obtained and presented to the Institute at the midwinter meeting, February 15, 1892.

At a meeting of December 19, 1891, the raising of funds for the new building was discussed, a sub-committee, Messrs. Lyall and Idell, were appointed to draw up a circular upon the matter, and the Corresponding Secretary was requested to secure the co-operation in each class of some one special member of such class in soliciting of subscriptions. The above committee rendered a full report at the semi-annual meeting, February 15, 1892, at which meeting the building scheme was fully discussed.

At a meeting held December 19, 1891, a committee, Messrs. Renwick and Rusby, were appointed to request of the Board of Trustees an additional representation of the Association, to the extent of one member, upon the Board of Trustees of the Institute. Through the kind effort of President Morton, this additional representation was obtained. An election was duly held for the choosing of two additional Trustees. The result has been the election, as the combined choice of the Alumni Association, the Executive Committee, and the Board of Trustees, of the gentlemen whose names will be announced by President Morton.

At a meeting held February 15, the resignation of Professor Riesenberger as editor of the INDICATOR was accepted, and upon his recommendation Mr. Johannes H. Cuntz was unanimously elected his successor.

At a meeting of May 20, a committee, Messrs. Bristol and Rusby, were appointed to draw up and submit to the Executive Committee a by-law completely governing election of Trustees. This form has been drawn up, approved by the Executive Committee, and will be submitted to the Association for discussion this evening.

At a meeting held June 22, 1892, the graduating class of the Institute was elected to membership in the Alumni Association.

At the meeting of June 22, 1892, it was decided that in future all elections of the Association should be by sealed letter ballot.

Respectfully submitted,

J. M. RUSBY,
Recording Secretary.

President Morton: The statement regarding the election of Alumni Trustees may be a little ambiguous as just given, and perhaps I should mention, in the first place, that the Board of Trustees authorized the addition of two, so as to make three Alumni Trustees, altogether. Therefore, in addition to one still holding office, two have been appointed from those named, the one for three years being Mr. Wolff; the one for two years being Mr. Hewitt. So that there are now three Alumni Trustees, Mr. Kent, Mr. Wolff and Mr. Hewitt. This arrangement is made, of course, with the view of having one new member elected each year, so that one member has a term of one year, another of two, and the third of three years to serve.

The President: The next in order is the report of the Treasurer.

Mr. Bristol presented the following report, which was on motion accepted and filed:

TREASURER'S REPORT.

HOBOKEN, N. J., June 22, 1892.

To the Alumni Association of the Stevens Institute of Technology:

Report for the year ending June 22, 1892.

I.—GENERAL FUND.

Receipts.

Balance in Fund June 15, 1891	$524.67	
Dues for 1891–92	762.50	
Dues in arrears	131.00	
Dues in advance	5.00	
		$1,423.17

Expenditures.

STEVENS INDICATOR, subscriptions to June, 1891	$87.00	
STEVENS INDICATOR, subscriptions June, 1891, to June, 1892	589.50	
Prof. A. Riesenberger, editing July, October and January INDICATOR	75.00	
J. H. Cuntz, editing April, 1892, INDICATOR	25.00	
W. L. Lyall, printing, postage and clerk hire	184.14	
W. H. Bristol, " " " " "	27.44	
Expenses, midwinter meeting	74.25	
		$1,062.33
Balance in Fund June 22, 1892	360.84	
		$1,423.17
Dues in arrears		440.00

II.—Beneficiary Fund.

Receipts.

Balance in Fund June 15, 1891	$618.01	
William R. King, '86, donation	60.00	
Loans repaid	170.00	
Bank interest	29.96	
		$877.97

Expenditures.

Loans	$100.00	
Balance in Fund	777.97	
		$877.97
Amount of outstanding loans	$641.82	
Total amount of Fund	1,419.79	

III.—Library Fund.

Balance in Fund June 15, 1891	$64.75	
Donation, William Kent, '76	50.00	
Balance in Fund		$114.75

IV.—Library Portrait Funds.

Balance in Fund, June 15, 1891 ..... $40.72.

Expenditures.

Portraits of Colonel John Stevens and Robert L. Stevens (with frames)	$39.00	
Balance in Fund	1.72	
		$40.72

V.—The Stevens Indicator.

Receipts.

From Business Manager	$745.80	
Alumni Subscriptions January to June, 1891	87.00	
" " June, 1891 to June, 1892	589.50	
		$1,422.30

Expenditures.

Deficit June 15, 1891	$63.22
Publication of July Indicator, 1891	201.00
" " October " 1891	231.77
" " January " 1892	274.10
" " April " 1892	278.64
H. F. Raetz, addressing Indicators and postage	22.25
Dr. T. B. Stillman, electros and drawings	28.00

American Society of Mechanical Engineers (cuts).....	3.00	
A. R. Williams, drawings.....	1.00	
Engineering Press, reprints.....	4.00	
Aug. Bastian, binder.....	4.35	
		$1,111.33
Balance on hand.....		310.97
		$1422.30
Outstanding bills		$133.00

Respectfully submitted,

W. H. Bristol,

Treasurer Alumni Ass'n.

The President: Has the Treasurer any further report to make?

Mr. Bristol: I understood that you would call up the matter with regard to those wishing to resign, and those who are in arrears. Is this the proper time for considering that?

The President: Yes; I think it is.

Mr. Bristol: Mr. Lyall has a list of those who have sent in their resignations.

Mr. Lyall: Letters have been received from the following gentlemen, offering their resignations: H. F. Dawes, '79; Alexander Wurts, '84; R. G. Smith, '89; Solomon Fechheimer, '90. The Executive Committee would like to know what the pleasure of the Alumni Association is in regard to these resignations.

A Member: I move that these resignations be accepted.

Carried.

Mr. Bristol: I have a list of gentlemen who are very much in arrears for dues. Is it proper to read the names?

A Member: I would like to say that I have seen a few of the names, and I am quite sure that some of them will change their minds in a short while, and pay their dues; so that I think it would be well to withhold the names for the present.

A Member: What is the objection to reading the names?

The President: There is no motion before the house at present. If there is no dissent we will not read the names.

Mr. Bristol: They are all from three to six years in arrears.

Mr. Collins: I have found it very good practice in some of the associations with which I have been connected, to have the members who are in arrears posted very conspicuously in the club room. I move that all members who are in arrears for two years be posted on the blackboard at the annual meetings of the Association.

A Member: I second that motion.

A Member: Is the motion debatable?

The President: It is.

Mr. Kent: I also had an experience with some engineering associations of the country, and it was their practice, when members got in arrears, for the council to take the matter into consideration privately, and if necessary, vote to extend the time of payment for one year, five years, or even for ten years, if it was thought desirable to keep a member in the Association. I therefore move to refer this motion and the whole matter to the Executive Committee, with power to act.

Mr. Collins: I accept the amendment.

Mr. Kent: My reason for making this motion is because in the engineering profession it sometimes happens that a man gets down at the heels, and has to withdraw his subscriptions to papers, societies, and everything else, but in a few years afterwards he finds himself again in good condition, pays off all back dues, renews his subscriptions, and becomes a member in good standing; and I do not think it is right to disgrace a man of that kind by posting his name for non-payment of dues.

The President: You have heard the amendment (which has been accepted by the mover of the resolution) that this whole subject be referred to the Executive Committee, with power to act.

So ordered.

The President: We will now listen to the report of the Alumni Trustee, which will be made by Mr. Kent.

Mr. Kent: At the last annual meeting of the Association I violated the precedent which had been established by my predecessor, Mr. Trautwein, that of presenting a long and formal report of the

Alumni Trustee, by giving a verbal report, in a few words, stating the fact that the Institute did not have much history except the mere record of progress, and that the only thing that I could report was that everything was proceeding all right, and that that was all there was to be said. I was severely criticised for that kind of a report, and was told that it was entirely out of place. I hope to do a little better to-night; but I do not purpose reading you a report, or presenting anything very formal. But I have another excuse for saying more to-night than I did a year ago, by reason of the fact that last year the Institute has been making history very fast, and there is consequently more to talk about. The Alumni Association has, ever since its organization in 1876, been in the utmost harmony with the Faculty and with the Trustees of the Institute; and it has always been quite a power, as you all know, in furthering the interests of the Institute. About six years ago the Alumni Association petitioned the Trustees to have an Alumni Trustee appointed on the Board of Trustees. For some reason or other the Alumni seemed to think (perhaps judging by the experience of other colleges) that it might require years to bring about the reform which they desired; and they were, therefore, somewhat agreeably surprised at having their request granted as soon as the petition was presented to the Trustees; and the necessary formalities for the election of such a Trustee were proceeded with, and Mr. Trautwein was made the Alumni Trustee for three years, and I succeeded him at the end of his term. The new Board of Trustees, having grown from three to four, and after having had four years' experience with the larger number, determined that a still larger body of Trustees was a good thing to have; and, accordingly, at the meeting in December, 1891, the Trustees enlarged themselves by adding five new members: Mr. Andrew Carnegie, Mr. Charles MacDonald, the President of the Union Bridge Company, Mr. A. T. McGill, Chancellor of New Jersey, Col. Edwin A. Stevens, the son of the founder of the Institute, and Mr. A. C. Humphreys, of the Alumni, making a Board of nine Trustees.

When that Board of nine Trustees held their meeting in January of this year, they said that it was right to enlarge still further ; and as the Alumni had petitioned for an additional representation on the Board of one member, the Board of Trustees, in common parlance, "went them one better," and resolved to have two new Alumni Trustees ; and, as you have already heard from the Secretary, at the meeting last night, the Board of Trustees selected Mr. Hewitt, of the class of '74, and Mr. Wolff of the class of '76—Mr. Hewitt for two years and Mr. Wolff for three years. The Board of Trustees, therefore, now consists of eleven members.

It gives me pleasure to report that, so far as I can find out, from the foundation of the Institute to the present time the finances have been well administered. The investments have been carefully made, and carefully changed when necessary ; and at the meeting last night, to give additional security to the investments of the Institute, the custody of the bonds and investments was placed in the hands of two men, Colonel Stevens and Mr. MacDonald. The finances of the Institute are managed by a committee of three members ; so that the finances of the Institute are in as good shape as it is possible to get them by any method known to man.

As you all know, the Institute has run against a stumbling block in the fact that, whereas we are only able to accommodate sixty Freshmen each year, there are applications for admission from about double that number of good men who can pass the entrance examinations, and we do not know how to get them in ; there is not room for them. This brings us right up against the question of finances. How shall we enlarge the Institute in order to take in that number of students? The question has been raised whether the enlargement of the Institute, so as to take in larger Freshman classes and graduate larger classes, is the proper way to grow; whether it is not better to raise the standard of the Institute so high, and make it so exclusive, that a very select number, say, only sixty Freshmen, shall be taken in each year, and that we shall turn out, say, forty mechanical engineers

from the Senior Class every year; so that the Institute shall grow good instead of growing big. I think that the Trustees in their own minds have settled the question, as far as they can, by determining that the better policy is to grow both big and good; that no college has ever lost prestige by growing large; because the largeness brought with it larger salaries to the professors and greater attractions to the students, and so drew them from a larger section of the country, and from all over the world, and so gave the college an international reputation. That has been the history of the great universities of the world. I think no university has ever succeeded in gaining prestige, reputation, or success, by confining itself to small classes. I think the feeling of the Trustees is that the growth of Stevens Institute should be limited only by the dollars and cents that it has at command. If there is any strong feeling on this question among the Alumni it is proper that they should be heard on the subject. If there is any reason why Stevens Institute should remain small and good, rather than become great, let us hear it. But remember, that in remaining small there is one disadvantage, that, instead of the Institute becoming known as a National school of engineers, or as a school which gathers students from all over the world, it will be likely not only to be known as a New Jersey school of engineering, but as a Hoboken school of engineering. The danger is intensified by the fact that, as it happens, the preparatory school here has so arranged its courses as to prepare its graduates for getting into the Institute, and there is more chance for a man to get into the Freshman Class of Stevens Institute if he goes through the preparatory school. It is not due to the fact that there is any favoritism shown to graduates of the preparatory school, but rather to the fact that academies and preparatory schools in other parts of the country do not make a specialty of preparing students to pass the entrance examination of Stevens Institute. If they did we might get a greater number of students from other schools. It will be a bad day for this Institute if it ever becomes known chiefly as the Hoboken Institute of Mechanical Engineering.

The Board of Trustees at the meeting last night transacted some other business. It was shown, as usual, that the outlay for the Institute exceeded its revenue by several thousand dollars ; but, fortunately, that deficiency is more than made up by the profits of the Stevens School ; so that we are very proud of the Stevens School for more reasons than one.

At the meeting last night President Morton carried out the intention that he had expressed at the last Alumni meeting by presenting to the Trustees $20,000 in bonds as an additional endowment to the Chair of Engineering Practice, but with the provision that the interest was to be deposited in a fund for the erection of a chemical building until the same shall have been paid for. (Applause.) No words of mine can make this statement any stronger, and your applause shows that it is sufficient.

President Morton also reported that plans were in project for the enlargement of the Institute Building by adding two stories to the present workshop; and this matter was referred to the Finance Committee with power to act. That is, the Finance Committee, when they see fit, or when they think it is advisable to do it, will enlarge the Institute by adding two stories to the workshop; and they will do this out of the revenue fund of the Institute, and without, as I understand it, encroaching upon the fund which is to be raised for the erection of a new building by the Alumni themselves and by their friends.

I might state also that at the meeting last night all the members of the Board of Trustees were present except Mr. Carnegie, who is now in Europe, and Mrs. Stevens, who is away from home. There was the liveliest interest shown by the new members of the Board of Trustees in the affairs of the Institute; and I have no doubt that the enlargement of the Board of Trustees will tend greatly to benefit the Institute.

There is a matter which I can speak of partly from the standpoint of an Alumni Trustee and partly as a member of the Alumni Association. There were six names presented by the Executive

Committee to be voted on for trusteeships at the meeting of the Board of Trustees last night, and some little embarrassment was caused by the fact that it was discovered that a circular letter had been privately sent out to some of the Alumni, but not to all, asking them to concentrate votes on certain three names. It is hardly possible that in an organization of this kind some kind of politics can be entirely excluded, but I think that this is the first time that anything of this kind has happened in connection with the vote for Alumni Trustee. The idea had not occurred to many of us, and consequently there was a good deal of surprise at the action. If it is right that such action should be taken and that letters should be sent around trying to concentrate the votes of the Alumni on certain desirable members, then it should be understood that such is the custom, in order that it may be done by others, and be free to all, and not be confined to any one self-constituted committee to send around such circular letters. It so happened that the six names presented did not really represent the general sentiment of the Alumni Association, but that three of them represented the sentiment of a select minority of the Association, while the other three were those that happened to be at the head of a list of scattering votes of the majority of the general body. This was an unfortunate state of things; but fortunately it did not do any harm, for the election last night resulted in the unanimous choice of Messrs. Wolff and Hewitt, and I have no doubt the result would have been just the same had no circular been sent out.

The President: There are other members of the Board of Trustees here and we shall be very glad to hear from any of them. If they have nothing further to offer we will proceed to the election of officers. The ballots have been prepared by the Executive Committee in accordance with the usual custom; but a second list of ballots has been handed me, and we will send both lists around together, and will ask that you vote by these ballots either by erasing the names of those that you do not desire to vote for, or by inserting the names of those that you may wish to vote for. I will ask Mr. Norris and Mr. Lyall to distribute these ballots.

Mr. Humphreys: Will you not first read the law which governs elections, so that we may understand as to the nominations? I do not happen to recollect how the election is to proceed, and I suppose there are others in the room who are in the same position.

Mr. Henning: I will say that in the Constitution and By-Laws there is no general direction about the election of officers, except that it merely states that this meeting shall elect those officers. There is no statement about the majority, or about the way officers are to be elected, or how members shall be named. The custom has been for the Executive Committee, in order to have a duplicate list of names, to procure a printed ballot containing two names for each office, and from those names the members are to select. This time, however, a third ticket was put in nomination, and that ticket was also prepared in the same way, so as to avoid any delay or loss of time in voting. There is nothing said in our By-Laws or Constitution, so far as I can find by looking through the INDICATORS, or the printed copy which I have, which says anything else about the election of officers.

Mr. Kent: I would like to ask whether both those tickets represent the nominations of the Executive Committee, or whether only one does.

The President: Only one of the tickets represent the nominations of the Executive Committee. That committee has nominated two members for each office, so that a choice can be made between the two. In the independent ticket but one name is given for each office, except where there are two officers to be elected, as in the case of Directors.

I will appoint Mr. Humphreys, Mr. Wolff and Professor Denton as tellers of the election.

I have been requested to emphasize the fact that *two* Directors are to be elected. There are the names of four on the Executive Committee's ballot, and of two on the independent ballot. Only two men can be elected.

Mr. Idell: I find my name on one of the ballots, and I wish to decline the nomination.

(The ballots were then distributed among the members, and while they were being counted by the tellers the President delivered the annual address.)

PRESIDENT'S ADDRESS.

I thank you, gentlemen, for honoring me with the Presidency of your Association. It was with pride and affection that I accepted the honor of presiding over an Association which binds us all to our dear Alma Mater: an Association which preserves the continuity of the ever-increasing number of concentric rings, which are some day to cover the globe, struck from our common center—Stevens.

It is pleasant to be here to-night, and it is good to look upon old friends and to welcome new ones. It is comfortable for all of us to know that whatever our differences of opinion, or diversities of calling, we are here with one purpose, one object—to love and honor our Alma Mater. It is fitting that we should stand here once a year and be counted for Stevens, and I congratulate those of you who are present on having planned your orbits so that you are traversing this point on this night.

I welcome the new members—the concentric ring of '92—and congratulate you on the honor of being Stevens Alumni. I frankly tell you that the years of bondage and travail through which you have successfully passed compel our admiration and praise; for while the improvements in the college course, since our day, make the work in the world easier for men, they make it harder for boys to become men. We are proud of you that you have won your way through, and we hail you as additional proof of how good a thing it is to be a Stevens Alumnus. We who are in the world can tell you that this education you have received at the hands of our honored Faculty is a great possession. Its utility stands proved, and the faith is upon us that some of the men who have it will some day be famous. Their fame will also be partly ours, for they will shed a glory upon Stevens, and whatever glorifies Stevens glorifies us. But though we cannot all be famous, by some signal act to cut away a load of superstition, or to open a gate to a new paradise beyond, it is given to all to do our duty, to take up the work at hand and do it faithfully. Work so done endures; and while it may not place laurels on the brow, it leaves contentment in the heart.

In the excavations of long-buried cities it has been discovered that the work done by the honest mason who laid up his stones plumb, and made his joints true, has endured, and down through the ages have come the evidences of work faithfully performed. The walls put up by the man who, while constructing a fair face, slighted the covered joints and put in a false filling, were found to have fallen, and there bereft of all concealment was unalterably exposed the evidences of his dishonesty.

As we pause to honor the honest workman of nearly 2,000 years ago, let us be thankful that we have such men around us to-day, and let those of us to whom it is not given to be famous take heart, and with refreshed courage go on doing our duty faithfully, quietly and courageously.

When I was notified of the results of your last election I was told that the duty of the President was to preside at the annual meeting and deliver an address. I thereupon thought over the subjects that concern the course of instruction at the Institute, which, by our experience in the world, we think could be amended or improved. There probably never was an Alumnus who did not think he could improve upon the college curriculum, and the younger the Alumnus the greater the improvements he thought he could make. Do not let me discourage any of our new members by this statement. If you have a plan for improvements and the time is not ripe, write it out on paper and file it away ready for use. Generally you will find that when the opportune moment for its presentation arrives you can improve upon it wonderfully. If we would thus make written comparisons of our views year upon year, we should be amazed at the lack of consistency in that thing we call the march of civilization.

I put down a plan for improvement in this way sixteen years ago to-night. It was in my thesis. The subject was "The Principles of Car Framing." When I entered the service of the Pennsylvania Railroad immediately after graduation I discovered, first to my horror, and then to my gratification, that that great system was not using a freight car frame in accordance with the principles deduced in my thesis, and that it was, consequently, scientifically deficient. I was gratified to think that I was to be afforded an opportunity to be of value to my company by correcting the great mistake. I therefore inaugurated a campaign in favor of my thesis. I found many who would listen and apparently agree with my scien-

tific demonstration, but none who would take action. Finally, after keeping the subject in view for five years, I was detailed to design a new stock car that would be superior to any of the cattle cars in use. I traveled all over the country examining the cars of our competitors, that being one of the first steps in the development of all railway improvements, and then studied the requirements of the traffic at the stock yards and on the road.

In my plan for the car, and the arguments I wrote for its adoption, I found the opportunity for the car frame of my thesis. In it went; and while some doubts were expressed by the superior officers on the frame, the car itself was considered so good that it carried the frame with it. A thousand cars were built, and in one year the results of service had proved that the side frame which I had cherished so fondly was no good—that with all my figures it had developed an irresistible tendency to drop down in the middle and cock up at the ends. Happily for me the other features of the car had proved valuable, it being the first of the 34-foot long bodies which has since become the standard length for a number of railroads, and as the remedy for the deficiency in the bracing was apparent and immediately applied I was not confounded.

With this in mind when I approached the subject of improvements in the college curriculum, I was affected with a modesty that was not born of the intrepid days of '76, when all the world seemed to need revision, and the men of our '76 felt as brave to tackle the earth as those of 1776 had been to tackle the Britishers. I came to the conclusion that I did not know very much about the college curriculum as it now stands, and that I had better take up some of those outside subjects upon which the students in no school, so far as I know, are instructed; subjects that our experience indicates are of importance to them. For illustration, let us consider the subject of organization. Engineers bred here may be divided into two classes: Those who become engineers *per se*, either as consulting engineers, professors, or the mechanical engineers of large corporations or great works. Second, those who become operating officers of important industries where the duties require the application of engineering knowledge to executive work. The latter class does not generally include discoverers or investigators in the abstract. This class follows, so far as their engineering work goes, in the footsteps of the mechanical engineer *per se*, and apply his discoveries to the needs of business. A large number of the Stevens

men are employed in the work of the last class, and many more are likely to follow. As it is essential that in doing this kind of work the engineer must act through an organization, it would appear advantageous that students in the Senior year be given a few lectures on the organization, covering in general the plan upon which the mechanical departments of our railroads are operated; the organization of large workshops, factories and shipyards, and the possibilities of temporary organizations in emergencies, as in the rebuilding of a railway under circumstances like those prevailing at the time of the Johnstown flood. I prepared some notes on these points as arguments for instructing the students on organization, but the more I thought on the matter the more apparent it became that it was not organization in the abstract that was desired at the present time, but organization in the concrete, not for the students, but for ourselves. Organization for the purpose of raising funds for Stevens. We have a right to be proud of the record of the Alumni Associatian, for with a membership of 400 men, the majority of whom have been out of college only five years, we have raised $17,000 for the extensions that are so essensial to the prosperity of our college. We have $33,000 yet to raise. There are many philanthropic men in our land, who, if they knew the benefits to be derived by future engineers from the accomplishment of our plans, would come to our aid. We must organize to reach such men. As a step to this end I would advise the appointment of a committee to prepare articles on the Institute, its object, its success, and its requirements for the future, together with a review of the work done by the Alumni Association for publication in the technical journals. It is usually accepted that an Alumni Association should have age before it can influence and benefit its Alma Mater; that the Alumnus may first do a little unto himself before he commences to do unto others; but here we are fifteen years old to-night—still in our teens—planning and working for Stevens. We cannot meet here to indulge in the pleasure of reminiscences, like the Alumni of classical colleges. We are so young, and there is so much to do that we have not time to live in the past—the needs of the future are upon us. This is not a time for retrospectives. We have to do with prospectives. And, therefore, thanking you for your kind attention, I make way for the business of the hour.

Mr. Idell: The Recording Secretary, after reading his report, mentioned the fact that he had some additional business to bring up during the latter part of the evening; and if in order I move that that business be now brought before the Association.

The President: Unless some objection is expressed the Recording Secretary will now present that business.

The Secretary: I was absent from the meeting of the Executive Committee which preceded this meeting, but I understood that a certain by-law, which a committee appointed for the purpose drew up, governing the election of Trustees and the election of officers, was to be discussed here. That is correct, is it not, Mr. Idell?

Mr. Idell: Yes.

The Secretary: There having been some doubts expressed with regard to the proper method of conducting elections, and there having been no by-law drawn up definitely laying down the method of procedure, a committee was recently appointed by the Executive Committee to draw up a by-law which shall completely cover the election of Trustees; and the committee have drawn up the following, which I will read, and so open the matter for discussion:

ALUMNI TRUSTEES AND THEIR ELECTION.

Any active member of the Alumni Association who has been graduated seven years or over shall be eligible to the office of Trustee.

Any active member of the Alumni Association who has been graduated two years or over, and is of good standing, shall have the right to nominate candidates for trusteeship.

Every voter shall be privileged to nominate two candidates for each vacancy to be filled.

Between the 1st and 10th days of April the Corresponding Secretary shall send to every voter the following: A printed list of Alumni who are eligible to trusteeship; a blank ballot upon which the voter shall write his nominations; a blank envelope in which the ballot shall be enclosed and sealed, an envelope stamped with the address of the Corresponding Secretary, in which shall be

enclosed the envelope containing ballot. Upon the face of this envelope, in lower left-hand corner, shall be printed the words, "Alumni Trustee Ballot." Across the back of this outside envelope the voter shall write his full name. Ballot shall close at midnight, May 31. An open meeting of the Executive Committee for the canvassing of ballots shall be held between the 31st day of May and the 10th day of June, and notice of this meeting shall be mailed to each member of the Executive Committee at least five days before date of meeting.

From all nominations thus made shall be chosen the names receiving the highest number of votes, at the rate of seven names for each vacancy to be filled. From these names the Executive Committee shall choose those of persons who are in their judgment most suitable for office of Trustee at the rate of three names for each vacancy to be filled. These names shall be submitted to the Board of Trustees for their election therefrom of a person, or persons to fill the vacant office or offices.

There was also action taken by the Executive Committee with regard to the method of procedure in the election of officers at these annual meetings; but we had better discuss these suggestions one at a time. The Executive Committee have approved of this plan as read. If there are any remarks about it we shall be glad to hear them.

Mr. Kent: These by-laws are very much like those in force at the present time. Is there any difference?

The Secretary: This has been very largely taken from a recommendation which was published in the INDICATOR some time since. There is no by-law in relation to this matter, but this was the method of election adopted at recent elections, although no regulation exists to this effect. President Morton had drawn up this form and recommended it, and we have followed it; but the Executive Committee thought it would be well to have a definite method of procedure adopted as a by-law. There had been some question raised in recent elections as to our method of procedure,

and it was the design of the committee to prevent any repetition of that.

Mr. Henning: When the INDICATOR is carefully read you will find that we did adopt those recommendations as our amendment to the by-laws, for the purpose of electing Alumni Trustees. I have studied out the thing very carefully, and feel sure that you will find by reference to the INDICATOR that we did adopt this plan in 1887. A motion was made here to adopt the report of the Executive Committee in the first place, and then the very last sentence of that report as published in the INDICATOR states that those recommendations were adopted by the Alumni Association.

Mr. Idell: I think I may offer a correction to that statement. In the account referred to by Mr. Henning the only action taken was upon a motion made by Mr. Kent, which referred the whole matter of the election of Alumni Trustees to the Executive Committee, with instructions to formulate definite rules and present them to the Association. I believe that has never been done until now.

Mr. Henning: If there is to be any discussion of this matter I would like to open it by reviewing what has been said. I think that these recommendations are too broad, too indefinite, and will lead to trouble. If the Alumni Association is going to elect candidates I do not see why, after a vote has been taken, the Executive Committee should step in and from those candidates select a certain number to their own taste and report them to the Trustees. Furthermore, I think that members of the Faculty will always be thrown out by the Executive Committee as candidates for Alumni Trustees for the simple reason that no member of the Faculty, except the President, can sit in the Board of Trustees over other members of the Faculty, and debate matters concerning them. Of course, it is understood that the Board of Trustees have invited him to be a member, and with perfect propriety; and whoever may happen to be President of the Institute should also be on the Board of Trustees. But I do not see why the vote should be scattered

over members who never can be eligible, in the eyes of the Trustees, to election as fellow members, by reason of the fact that they are already connected with the Faculty. May I ask Dr. Morton whether he thinks it advisable that members of the Faculty (except the President) should be candidates for election as Trustees, and as Trustees debate questions relating to the government of the Faculty?

President Morton: It is my impression that such an arrangement would be very unusual, and it does not seem to me desirable.

Mr. Henning: That is what I thought; and therefore I have brought up the point that it is very undesirable. And if those candidates are undesirable, why should we vote for them at all? What is the object of voting at all except to express an opinion? In order to get an expression of opinion some action must be taken. We all know that in each one of these elections this very case has come up: a candidate has received a number of votes, and his name has had to be withdrawn by the Executive Committee because they knew that he would be an undesirable candidate on the Board of Trustees for the reason that he was a member of the Faculty. Why should we pass an unsatisfactory amendment, which may stand for years to come, when we can so easily arrange at the present time what may be necessary for the future, without requiring further amendment? Why not present satisfactory by-laws now, which will stand? The Alumni Association before this meeting consisted of 389 members, and with the class now coming in there will be considerably over 400 members. We are therefore a very strong body. We are able to see through these points, and we should have our by-laws so arranged as to avoid any possible stumbling blocks in future.

Furthermore, I do not think that seven members should be selected for each vacancy, and then out of these seven some members selected by the Executive Committee. If we send out a sealed letter ballot every member has time enough to find out for himself who the proper candidates are; and when the members of the Association say by their votes that certain members are the most

desirable men to be presented to the Board of Trustees, there is some reason for that expression of their opinion; and I do not see, therefore, why our officers should go to work and select from these a certain number of men to be presented to the Board of Trustees for them to select from. If we give two names for each vacancy to the Board of Trustees, I am quite sure that the opinion of the Alumni Association, as a body, is not so far wrong as to give two names which shall both be unacceptable to the Board, so that the Board of Trustees would be unwilling to accept either of them, and would have to refer the matter to the Association to take another vote for candidates. Therefore, I do not see why, after going through this formality of selection by a sealed letter ballot, that this selection should be simply thrown aside because the Executive Committee says so. Furthermore, I think that the exclusion from voting for Alumni Trustee candidates, for non-payment of dues, should not be so limited as it has been heretofore; and these new resolutions are not as definite in that respect as they might be. Will you please read again the section with regard to qualifications for voting?

The Secretary: "Any active member of Alumni Association who has been graduated two years or over, and is of good standing, shall have the right to nominate candidates for trusteeship."

Mr. Henning: We have nobody to say what constitutes a member in "good standing." We do know that the neglect of a man to pay his dues for three or four years rather indicates a lack of interest in the Association; and we think that the fact that members take an interest in the Institute and in the Association, is entitled to be taken as a criterion of the propriety of such persons expressing by their vote anything they may wish to say with regard to their interest in the Institute. Therefore I think that that clause is too broad, and might be changed. With regard to the time between issuing this ballot and the time for closing it, I wish to say that I think it is too long a time. It is so long, in fact, that many members will forget to vote altogether. It is over a month and a

half. If you call in the ballot within twenty days every man would try to find out promptly for whom he should cast his vote; but if they have a chance to pigeon-hole the matter it will likely be forgotten. If we limit the time to one month it will give the Trustees ample time to select the candidate, and give the committee time to count the ballots; and that is all that is necessary. If you allow them to take two months, I think it will result in very many votes not being cast. This last ballot cast for Alumni Trustee does not represent the voice of the Association, because, as I understand, 167 votes were thrown out because they were from members who had not paid their dues, not because they do not want to pay them, but simply because they had pigeon-holed their bills. Therefore this vote does not represent the voice of the Association; and we must take some other means to get an expression of the opinions of the members of the Association with regard to candidates proposed for election to trusteeship.

Adhering to the views which were expressed by Dr. Morton some years ago I have drawn up a set of resolutions, in connection with others, which I desire to read:

FOR ELECTION OF ALUMNI TRUSTEE CANDIDATES.

Resolved, (1.) That active members of Alumni Association only, and of seven years' standing and over may be candidates.

(2.) That all members in any manner connected with the Faculty or the Institute shall be ineligible as candidates.

(3.) That only active members of two years' standing and over shall have the right of voting for Alumni Trustee candidates.

(4.) That all members in arrears of dues for a period of two years previous to such elections shall be disfranchised from voting for Alumni Trustee candidates.

(5.) That each member entitled to vote for Alumni Trustee candidates may name two candidates for each vacancy to be filled.

(6.) That the ballot shall close the third Wednesday in May, and that the Executive Committee shall count the vote and thereupon report the successful candidates to the Board of Trustees,

stating the number of votes cast for each; the report to give two names for each trusteeship to be filled, and to contain the names of candidates receiving the highest number of votes.

(7.) That a sealed letter ballot, containing the foregoing conditions, be issued with a list of available candidates by the Executive Committee on the third Wednesday in April; that this circular letter shall also contain a blank ballot slip in a blank envelope to be enclosed in an addressed envelope marked "Alumni Trustee Candidates," across the back of which shall be the endorsement of the member voting.

Mr. Kent: I would like to ask you to read again the clause relating to amendments to the by-laws.

Mr. Henning: It reads that twelve members shall constitute a quorum, and a two-thirds of the members present may amend the by-laws at any meeting. That is what these printed by-laws say.

The Secretary: "These articles of Association may be amended at a regular annual meeting of the Association by a three-fourths vote, twelve members constituting a quorum for the transaction of business."

Mr. Kent: I am a little surprised to learn that there is no by-law relating to the election of the Alumni Trustees, but I accept Mr. Idell's statement of the fact that there is none. Fortunately, there is no election to be had for Alumni Trustee until next April or May; and as we have a midwinter meeting I think it would be advisable to refer both of these proposed resolutions to the Executive Committee, and request the Executive Committee to draw up from these two sets of resolutions such by-laws as they may propose, and that the proposed by-law be published in the INDICATOR, so that all the Alumni may have a chance to study up the question and be prepared to vote on it at the midwinter meeting. I therefore move to refer both these documents to the Executive Committee, with request to take action thereon.

Mr. Idell: I would like to say a word with special reference to the time that the ballot is to be held open. If it is to be open

for one month only I think it will be impossible to reach some of our members. We have one member in Italy, and some in South and Central Americas. The ordinary time for a mail to reach points in South America is one month If a member is off in the field it may be two months before a letter reaches him. I think that the ballot should remain open at least a sufficient length of time for the ballot list to reach and to be returned from our more distant members.

A Member: I would like to ask a question for information. I understand Mr. Henning's suggestion to be that each Alumnus who votes shall hand in two names for each office, and that the Executive Committee shall present to the Trustees the two names for each office having the highest number of votes.

Mr. Henning: Yes; and it does not leave the Executive Committee, who are the clerks of the Alumni Association, to select a man of lower standing than the candidate receiving the larger number of votes, as has been the case heretofore.

The Secretary: Mr. Henning questions the policy of having certain men nominated by the Alumni Association, and then having the Executive Committee select from them; and he terms the Executive Committee the "clerks" of the Alumni Association. I do see a use in it. It strikes me that by selecting six or seven men, and then letting the Executive Committee choose from them, we are assured that men will be selected who are the most popular and who are the best qualified to fill the office, in the estimation of the Alumni Association at large. The Executive Committee are supposed to amount to a little more than clerks. They are men who make a business of informing themselves with regard to the qualities of the various candidates presented, and the advisability of their being elected; and I think that that is an excellent thing.

The President: The motion before the house is that the two plans suggested shall be referred to the incoming Executive Committee. Are there any further remarks?

Mr. Henning: The motion was that the committee report at the midwinter meeting, whereas, according to the Constitution, it

is at the annual meeting only that we can take into account any proposed change in the by-laws.

Mr. Kent: We can easily get over that objection by now passing an amendment to the by-laws which shall cover the method of making amendments. I will say that such amendment might be that, as we now have power to amend the by-laws, we can amend the by-laws by amending that clause relating to amendments, stating that any amendment can be passed upon at any meeting of the Association, either at the annual or at the midwinter meeting, provided notice of such amendment has been given at the previous meeting, and published in the INDICATOR.

Mr. Henning: I would like to read some other amendments to the Constitution referring to that matter.

Mr. Kent: That gets over the difficulty entirely.

The President: In order that we may not become confused over this, I will now put the motion which is pending. All in favor of Mr. Kent's proposition, that this matter be referred to the incoming Executive Committee, who shall report a plan or rule which in their opinion shall serve the purpose to the best advantage, and that that shall be voted upon at the next meeting in the winter, and that the report of the Executive Committee be published in the INDICATOR, so that it may be thoroughly understood and intelligently voted upon at our midwinter meeting; all in favor of that will say, *aye;* those opposed, *no.* It is so ordered.

Mr. Henning: I am sorry that it passed in that way, for the reason that at present we cannot pass any such thing at our midwinter meeting.

The President: We shall trust to you, Mr. Henning, to help us out in that.

Mr. Humphreys: The tellers wish to ask for instructions. There are six votes here by proxy, and your committee desires instructions (and the more particularly since it affects the result) whether they are to be counted or not.

Mr. Henning : I would like to say that I have sent out for these proxies in order that absent members may have as much privilege in voting for officers as the members present have. A majority of the members are away from here, and I have sent to absent members at least forty letters requesting proxies ; and I have received some flattering answers. Naturally, the members are entitled to have an opportunity to vote, although they cannot be present ; and for that reason I have cast these ballots with the proxies, especially in view of the fact that at one of the meetings of. the Executive Committee a proxy was on hand, made out by an officer to vote in his absence, which, of coure, is not right ; but at the annual meeting every member of the Association should have the opportunity to vote, either by voice or by proxy. I know that a proxy was on hand, although not used at the meeting of the Executive Committee, and I do not see any impropriety in here voting proxies of members who have expressed a desire to be represented.

Mr. Kent : Have these members who present proxies had an opportunity to vote on all three of the names presented here, or were they solicited, in asking for proxies, to vote on a certain set of names ?

Mr. Henning : I don't think it makes any difference which way it was. Some of them were told that such members would be voted upon, and others allowed me to use my own judgment in voting for whomever I pleased, as is customary when proxies are given.

Mr. Kent : I think that it makes all the difference in the world. I think that this thing had better be stopped right here and now. This is the entrance of ring politics into our Alumni Association. I am opposed to getting votes in advance for any particular candidates while the members who did not get these circulars, and who come here to-night to vote, have no other option than to vote for one of these three names, and have only a few minutes in which to make up their minds how they shall vote, while the members who

did give proxies had arguments presented to them as to why they should vote for some particular one. Of course, a self-constituted committee asking for proxies could in that way fix the result of the election as they pleased. I therefore move that the votes by proxies be thrown out.

A Member: I second the motion.

Mr. Henning: I have in view a set of by-laws to cover that case in the future. I have studied the present method in use and am thoroughly dissatisfied with it. I think that there is altogether too much spontaneous action at our annual meetings ; that the few who come here do everything, and that the outsiders never have a chance to find out what is going on at the Institute. If you will let this thing stand as it is, and will listen to what will be presented later, you will see that nothing is intended except to do this thing in the interest of the Association, and of every member of it. Every member has a right to vote and I do not see how we can take that right away from him. But what can a member who is a thousand miles away do except by expressing his opinion through some one else? That is just what these members have done. Some of them knew who were to be voted for to-night; and with that knowledge they did send their proxies; and I do not see how you can take that vote from him; or how can you take such action as is now proposed.

Mr. Humphreys: I would suggest that in view of the fact that no such practice has obtained in this Association heretofore, and also in the absence of any direct rule permitting us to take such action, it would be unwise to take it at this time. I think it would be better for Mr. Henning to wait and try to pass the rule which he proposes, and so ascertain the sense of this meeting in that way. If it passes, well and good; it will be all right in the future. At the present meeting it is of very little importance.

Mr. Idell: If the Recording Secretary had continued the reading of the resolutions and recommendations which he has in his hands, facts would have been brought before the meeting which would have shown the members present that the Executive Com-

mittee has a change in the method of electing the officers and directors of the Association, which they think will cover this case so satisfactorily that no trouble like this will again arise. The statement has been made here that proxies were used in a meeting of the Executive Committee. I have been on the Executive Committee for a number of years, and I do not recall an occasion when a proxy was used. A proxy was left in the hands of one of the members at one time, but that proxy was not used.

A Member: What do the by-laws say on that point?

The President: I understand that there is no reference to the matter at all.

Mr. Kent: I think that the by-law does say something about elections at annual meetings—that the officers shall be elected by a majority of the votes present. This would necessarily exclude proxies

Mr. Henning: No, sir; proxies are just the same as members present. I have brought this matter up for the purpose of having a discussion upon it, and for the purpose of letting you know that there are members who want to have their opinions expressed. Something must be done to give these men an inkling of what is going on. I want to hear what is to be said about these proxies. I want to know what the Association thinks about them. I don't think it is right for one-fifth of the members of the Association to come here and tell the other four-fifths what they are to do. That is the point I am making. Here we are, but one-fifth of the whole Association. Shall we say what the Association is to do, or shall they say what we are to do? I have heard what you say; and if you will allow me I will withdraw those proxies.

The President: There is a motion before the house that the six proxies be not counted.

Mr. Wetzler: In view of the fact that Mr. Henning has withdrawn the proxies I think it will be better to allow that motion to lapse. His withdrawal of those proxies settles the question, does it not?

The President: I do not think it does. I think the better way is to vote on the motion. All in favor of it may say *aye;* all opposed, *no.* The *ayes* have it. The proxies will not be counted.

Mr. Idell: I would ask the Recording Secretary to read the recommendation of the Executive Committee covering annual elections.

The Secretary: "The Executive Committee recommends that in future the elections for officers and directors of the Association be by sealed letter ballot, in which all members participate, the details of the ballot to be left for the next Executive Committee."

Mr. McNaughton: I move that a committee be appointed to thoroughly revise the by-laws.

A Member: I second that motion.

Mr. Henning: I would like to say that I had that in view in a further resolution which I would like to offer.

The President: I am afraid that Mr. McNaughton has got ahead of you. We have heard the motion that a committee be appointed to revise the by-laws. It is now open for discussion.

Mr. Kent: I am in favor of passing Mr. McNaughton's motion, but I think it would be well to simplify that by passing an amendment to the by-laws which will make it possible for us to amend the by-laws in midwinter. If the committee reports at the midwinter meeting we may not be able to get the by-laws amended until the annual meeting. I therefore move that the amendment clause in these by-laws be amended so as to read that amendments—

The President: There is a motion already before the house. Do you move to amend that motion?

Mr. Kent: I will make it as an amendment to the motion, and for the purpose of facilitating matters. I move that the amendment clause of the by-laws be amended so as to read as follows:

"Amendments to these by-laws may be made at either the annual meeting or the midwinter meeting, by a two-thirds vote of those present, provided notice has been given of such proposed amendment either at a previous meeting, or by publication in the INDICATOR before such meeting."

That last clause will enable the committee to announce in advance what they propose as an amendment to the by-laws; and then we can vote on it at the midwinter meeting.

Mr. Henning: If the gentleman will withdraw the motion I will present some resolutions which have been talked over among several of the members, and which I consider put the whole thing in a nutshell. We have several resolutions here which will arrange the whole matter. Instead of discussing this motion, which is a spontaneous matter, and has not been thought of before, why cannot the members wait until we can get to this business properly and then see what it is? If these gentlemen will withdraw their motions, I think it will save time, and then we can have it all arranged so as not to lose the time we have been losing each year.

Mr. McNaughton: I do not see what objection there can be in passing the motion, and then letting Mr. Henning hand whatever papers he has to the committee.

Mr. Henning: I want all the members present to hear what this is before it is handed to the committee. If you will allow me to read this it will settle the whole matter.

Mr. Humphreys: That might be unfair to the rest of us. A few of us have digested those resolutions, but the rest of us have not had the opportunity.

Mr. Henning: You do not have to adopt this now, but I think you will save time if I let you know what it is. The resolutions I want to offer are as follows:

AMENDMENT TO ARTICLE VIII.

Resolved: (1.) That any five members may offer amendments to the Constitution and By-Laws over their signatures, which must be in the hands of the Executive Committee in time to be issued with the ballots on the third Wednesday in April.

(2.) That such amendments shall be voted upon as to their adoption or rejection by sealed letter ballot issued by the Executive Committee, about the third Wednesday in April.

(3.) That all votes on amendments, in order to be counted, must be in the hands of the Executive Committee three (3) days before the annual meeting.

(4.) That the Executive Committee shall report the result of votes at the annual meeting.

(5.) That it shall require a two-thirds vote of the membership to carry an amendment.

A Member: I call for the question on Mr. McNaughton's motion.

A Member: I would like to ask how many members are to be on the committee provided for by Mr. McNaughton's motion.

Mr. McNaughton: I merely made the motion in that way to get the thing started. It really does not make any difference whether it be referred to the Executive Committee or to a special committee.

The President: All in favor of Mr. McNaughton's motion will say *aye;* opposed, *no.* It is so ordered.

Mr. Kent: I now call for the putting of my motion, providing for amendments to the by-laws at either the annual or the mid-winter meeting.

(Mr. Kent's motion, as above, is read by the stenographer.)

Mr. Henning: We have found out that publishing in the INDICATOR does not bring it before all the members. I do not think that that is sufficient. After they have studied it, what good does it do them? What good does it do for those who are here to take action, when others cannot express an opinion or act at all? If it is left to a ballot, then all can express their opinion

Mr. Kent: Mr. Henning does not seem to understand that this amendment is to be only temporary, and to last for six months only, to enable us to change the present by-laws at the next midwinter meeting. If we do not pass it to-night no action can be taken at the midwinter meeting. This simply provides a way to let the desired amendment be acted upon at the midwinter meeting.

(Mr. Kent's motion was then carried.)

The President: It might afford us some pleasure now to hear the report of the tellers as to the election.

Mr. Wolff: The acceptable candidate for the Presidency is Mr. Field, who received 22 votes out of the total number of 59 cast; Mr. Van Atta received 21, and Mr. Rea received 16.

For Vice-President, Mr. Wetzler received, 23 votes, Mr. Woodman 20, Mr. Dinkle 16.

For Corresponding Secretary, Mr. Raqué received 41 votes, and Mr. Flack 17.

For Recording Secretary, Mr. Mitchell received 22 votes; Mr. DeHart 19, and Mr. Dinkle 16.

For Treasurer, Mr. Bristol received 44 votes, and Mr. Anderson 15.

For Directors, Mr. Lyall received 29 votes, and Mr. Dixon 24. Mr. Kursheedt received 16 votes, Mr. Bayles 12, Mr. Idell 16, Mr. Flack 18.

Mr. Kent: I wish to ask, for information, whether the Constitution and By-Laws allow the election of officers by a plurality vote; if so, all right; if not, we shall have to vote again.

The President: Article IV., Section 1, simply states that officers shall be elected by ballot annually at the regular meeting of the Association.

The report of the tellers prevails. The gentlemen they have declared elected are so elected.

A Member: Does that mean that they shall be elected without a majority of the votes?

The President: It means that they received the most votes, and that they are elected.

A Member: I was about to offer a motion to make the vote unanimous so as to settle that question.

The President: The chair will entertain that motion. All in favor of that will say *aye*; opposed, *no*. The election is unanimous.

Mr. Henning: Now I would like to offer a set of resolutions to be acted upon at the midwinter meeting.

The amendment as to the election of Alumni Trustees I have already read. I offer the following as an amendment to Article VI. Section 1:

"Fifty members present at the annual meeting shall constitute a quorum."

The other amendments relate to the election of officers. I would like to say that Mr. Wetzler has approved and seconds them, and therefore it will save time if I read them over. I offer the following amendments to Article III., Section 4.

FOR ELECTION OF OFFICERS.

Resolved: (1.) That all officers shall be elected by a sealed letter ballot.

(2.) That candidates for offices may be proposed by three members not officers, and the names shall be sent to the Executive Committee over the signature of the proposers.

(3.) That the Executive Committee may name a ticket, and shall do so in case there are no other nominations.

(4.) The names of all candidates with indications by whom nominated shall be issued by the Executive Committee, with a blank ballot slip.

(5.) The ballot slip is to be enclosed in a blank envelope, which itself is to be enclosed in the addressed envelope, across the back of which is the endorsement of the member voting.

(6.) The names of candidates must be in the hands of the Executive Committee in time to be issued with the ballot for Alumni Trustee candidates, on the third Wednesday in April, and election shall close three days before the annual meeting of each year.

(7.) Ballot for officers is to be counted by the Executive Committee immediately after the close of the election, and results reported by it at the annnal meeting.

(8.) Should there be a tie vote for any officer, then a majority vote of those present at the annual meeting shall determine which of the candidates shall take the office.

Resolved: That the Executive Committee be instructed to draw up a correct copy of the Constitution and By-Laws and spread them upon the minutes of this meeting, in full.

It is not necessary to discuss this now, but it can be discussed at the midwinter meeting.

Mr. Kent: I would move that all the suggestions we have heard relating to amendments to the by-laws, including those which have been already referred, and any others which may be received, be referred to the Executive Committee for their action.

The President: You have heard the motion before the house that all these proposed changes in the by-laws be referred to the Executive Committee, and be considered at the midwinter meeting. (Carried.)

Adjourned.

THE RECENT ALUMNI TRUSTEE ELECTION.

NEW YORK, June 30, 1892.

To the Editors of THE STEVENS INDICATOR:

As there are several gross misstatements in the concluding remarks of Mr. Kent's report as Alumni Trustee, presented at the regular annual meeting of the Alumni Association last week, which are designed to reflect unfavorably on the action of what Mr. Kent, *at the meeting*, was pleased to term a "self-constituted committee" and a "clique," a few comments are in order. So far as Mr. Kent's convictions, if indeed he have any in this matter, are concerned, they are not worth arguing about. They would certainly not have prompted this letter, had he not attempted to force them upon the Alumni at large.

If the action of this "self-constituted committee" had been properly represented to the Board of Trustees, no embarrassment, as alleged by Mr. Kent, would or could have been caused

It is decidedly untrue that our circular letter was issued to what Mr. Kent called a clique. It was, on the contrary, presented o and discussed by nearly all interests, Mr. Kent alone and his

adherents not being consulted, and that for very obvious reasons. There was no secrecy whatever about the letter, and the names on it are proof that it was not the work of a clique. Mr. Kent's friends had a copy of the letter more than a month before the meeting of the Alumni Association, and had Mr. Kent so desired, he could have learned very easily that the remarks made by him at the meeting were untrue and uncalled for. They were simply the expression of a disgruntled and baffled faction.

Other developments have shown that whatever action was taken was for one object alone — viz., to further the interests of the Institute and of the Alumni Association. Mr. Kent's statement that* "It so happened that the six names presented did not really represent the general sentiment of the Alumni Association, but three of them represented the sentiment of a clique, while the other three were merely those that happened to be the choice of the whole general body," is altogether unwarranted. As a matter of fact, the three candidates reported to the Board of Trustees which were named on the circular letter received 52, 48 and 42 votes, respectively, while the three remaining names received 30, 15 and 10 votes each. Still, Mr. Kent asserts that the latter received the general support of the Association.

It would seem to us, on the other hand, that the degree of general support is expressed by the number of votes given to a candidate, and not by the opinion of the Executive Committee or of an Alumni Trustee.

With what right or reason, however, we ask, does Mr. Kent challenge our privilege to communicate with members of the Alumni Association who have no source of information on Institute matters such as he and his friends constantly have? Attempted coercion in this matter of voting was no part of our method. Everyone addressed by us was left to follow his own inclinations in selecting candidates, and that these should have been so distasteful to Mr. Kent and to the interests with which he is identified is a matter of interesting consideration. At other colleges the method followed by us is general in selecting Alumni Trustees.

Since Mr. Kent evidently made no effort to ascertain or recognize the conditions under which we acted, he certainly and outra-

* We here quote Mr. Kent's remarks as reported by the official stenographer.

geously prostituted his official position as Alumni Trustee in presenting his views of the case as explained to him by his friends. This is more particularly true since he well knew that any remonstrance from us at the meeting would have provoked unpleasant discussion, and would, therefore, be avoided by us.

Respectfully,

GUS. C. HENNING, '76.
R. S. KURSHEEDT, '80.
ALBERT SPIES, '81.
C. W. THOMAS, '84.

ATHLETICS.

"STEVENS wins the Intercollegiate Championship." We are sure that these words will wake in the heart of every true Stevens man an echo of that jubilation which broke forth when the glorious news came over the wire from Bethlehem, that our boys had beaten the confident Lehigh team and won the championship. For, not only is the result the summation of years of hard and earnest work, but it is the lasting record of our prowess over two of the strongest teams that Lehigh and Johns Hopkins have ever put in the field.

It was known last year that the team was unusually strong, and that the score of the Johns Hopkins game was no trustworthy indication of its relative strength. So, when nearly all of the old team reported for practice this year the hopes of the lacrosse men rose high in the thought that at last the time had come for Stevens to take her rightful place as leader.

And right nobly has the team fulfilled the most ardent hopes of its supporters.

Under the strict discipline and able leadership of Captain Martin, backed by the skillful training of Mr. Giroux, the team has proved its superiority over its opponents in all points of the game. In team work and in body checking they have especially excelled and the Lehigh victory was won largely on this account.

The victory over Johns Hopkins after only three weeks' practice was most encouraging, but the sweeping defeat inflicted upon Lehigh less than a month later shows the perfection to which the play of the team, both individually and as a whole, had been brought.

It is hard to choose a few men from a team of such superior players for special mention, but the steady work of Coyne in goal, and the fine playing of H. Cuntz and Martin for the defense and W. Cuntz. Maynard and Kellogg in the attack is worthy of especial notice.

Taking the team as a whole it is seen that the defense has proved a little stronger than the attack.

In general team play, and especially in clever body work, it has shown its excellence; the superiority in body checking being especially effective against teams which excelled in passing. Another point which deserves especial mention is the splendid physical condition of the team just before the games.

All credit for the victory belongs of right to Captain Martin and Mr. Giroux, by whose energetic and skillful training it was made possible. While it is a matter of universal regret that Captain Martin is prevented by pressing engagements from taking a post-graduate course in spelling, etc., it is the earnest hope of the college that Mr. Giroux may live long and prosper, to instill the knowledge of the fine points of the game into the coming players, and keep old Stevens ever in the van.

It will be seen from the records that the team suffered only one defeat —that at the hands of Johns Hopkins, at Philadelphia; and this would

have been impossible had not Stevens been weakened by the absence of two of her best men, and Hopkins strengthened by Cone, of U. of P., perhaps the best defense player in the country.

The account of the Hopkins game, at Hoboken, given below, is taken from the Baltimore *American:*

"After a hard, desperate fight, that was uncertain up to the final call of time, the Johns Hopkins Lacrosse Team lost the first championship game of the intercollegiate series to Stevens Institute, by a score of 4 to 3. The game was one of the finest ever seen here, and was sharply contested by both teams. Superior training and longer practice, however, gave Stevens advantages, for which Hopkins' brilliant individual playing could not compensate. The Baltimore team tipped and threw well, but was weak in sprinting and body checking. The defense, in spite of its strenuous efforts and Penniman's magnificent work, was clearly outplayed. Mitchell was obliged to cover a wide circuit and three of Stevens' four goals were scored when he was away from the posts. The game was marred by a cold, drizzling rain that converted the beautiful campus into an expanded toboggan slide and rendered clever body work more or less problematic. Shortly after 3 o'clock, Referee Miller, of the Staten Island Athletic Club, faced Reese and Willett in the center.

"Stevens won the ball and Maynard threw down the field. Cameron checked MacCord and Penniman returned it to center. Symington picked up well and started down the field with Willett close upon his heels. Stopping shortly he dodged off at an angle. In trying to follow Willett lost his footing, and with a sharp cry of pain fell to the ground. Time was called, and the injured player was at once carried off the field. Examination showed a sprained knee, making necessary, according to the rules of the league, the retirement of his opponent, Reese. During the remainder of the game each side played with but 11 men.

"Play was resumed with a clever stake-out by Martin and a long throw by Maxfield. W. Cuntz missed a try at goal and Stevens returned. Roszel tipped to Symington who sent the ball hard for the posts. Coyne stopped it cleverly, however, and a moment later did the same thing with a hot drop from Griswold. Maxfield and Maynard now carried the ball into Hopkins' territory. A critical scrimmage followed and Mitchell chased the ball behind the post. A part of Stevens' attacks were, however, behind him and the rubber was tipped to W. Cuntz, who slammed it between the bare posts, thus scoring Stevens' first goal after 12 minutes' play.

"The ball now traveled steadily from posts to posts. Roszel and Abercrombie ran and dodged well, and the defense field played with life and desperation. Mitchell stopped a fine drive from MacCord and Penniman returned. Roszel tipped to Morris, who drove in Hopkins' first goal after seven minutes' play. Both sides now warmed up and scrimmages waxed numerous. Coyne stopped a fine drive from Symington and in his excitement banged Morris on the head. Martin threw to Maynard, who drove the ball behind the posts. Mitchell followed, leaving Cameron between the posts. In a moment Cuntz scored Stevens' second goal by a clean drive.

The ball now steadily hovered about the Hopkins' goal. Penniman's long throws brought salvation again and again. Finally, after 13 minutes' unequal work, Symington tied the score by chasing the ball behind the posts, tipping neatly to Morris, who drove it in. Score at end of first half, 2 to 2.

"During the second half, in spite of brilliant playing by Abercrombie, Penniman and Roszel, the work of the Hopkins team showed the effects of the long strain. Penniman was the only man who could do anything against the powerful Stevens' attack, and again and again he sent the ball far down the field. The fifth goal was scored by Hopkins after 17 minutes' play on a long, clever run and tip by Abercrombie and a long shot from the field by Symington. One minute later, before the cheers of the small Hopkins contingent had died away, the score was again tied by Maynard's scraping the ball from the face scrimmage, tipping to Kellogg, he to MacCord, who, after sharp checking, sent it between the again undefended posts. It now became clear that, other things remaining equal, it was Stevens' game. Penniman was doing Hopkins' entire defense work and saved imminent goal after goal. Occasionally the ball got into Stevens' territory and Morris and Symington each shot for the posts. Coyne's steady work, however, kept the score blank until, after 20 minutes' play, the deciding goal was scored by W. Cuntz on a poke from a scrimmage in goal.

"Every man on the team deserves praise. There was very little fumbling. Captain Martin has every reason to be proud of the team he has developed. To pick out the men to be complimented would be to run through the whole list. Especially brilliant was the work of Corbett, Maynard, MacCord, and W. and H. Cuntz. The teams were received after the game by the Stevens chapter of Beta Theta Pi."

We desire to acknowledge our indebtedness to the *Lehigh Burr* for the substance of the following account of the Lehigh game:

The 28th of May was a perfect day for lacrosse, but the setting sun looked down upon a large crowd of cheering Stevens men bearing their team from the grounds covered with the glory of having defeated Lehigh and won the intercollegiate championship for 1892. The Stevens team arrived at 3 o'clock from Hoboken, and were met at the Union Depot with the Stevens' cheer from a number of their men, who were here on an inspection tour.

The game was called at 4:18. From the beginning to the end each team gave the other a hard, fierce fight. Time and again the Lehigh attack shot for goal, but the ball was prevented from passing between the posts by the bunching and splendid work of our defense. Our attack also played a brilliant game, and in the end proved their superiority to the Lehigh defense, as the score will show. The cheering was well kept up by both colleges throughout the game, Percy Mackenzie leading the crowd of Juniors in the good work for Stevens.

During the first half the fighting was very even, although the ball was kept well down on Lehigh's side of the field. Long shots for goal by

the Lehigh attacks and long throws by Martin, Maxfield and Cuntz and the steady playing of Coyne in goal were the special features of the play. Stevens took fewer shots for goal, but they were at shorter range and more dangerous. Lehigh was passing better, but the Stevens boys were sticking close to their men, and their superior body checking was beginning to tell. Van Cleve, of Lehigh, was disqualified for the latter part of the half for slugging Griswold.

The second half opened with the score 0—0. Both teams played with the utmost determination. Long throws from one end of the field to the other, brilliant intermediate work, and red-hot scrimmages in front of goal succeeded each other with bewildering rapidity for the next half hour. Finally, 10 minutes before time, Kellogg secured the ball on a long throw from our defense, and scratched it through the Lehigh goal, scoring the first point for Stevens amid the wildest enthusiasm.

This misfortune seemed to discourage the Lehigh men, who had been struggling to keep the game a tie, and our boys, fired by their success, threw two more goals at short intervals. The second goal was thrown by MacCord from a pass by Hutchinson, and the third was driven in by Kellogg just before time was called. Final score, 3—0.

The whole team put up a magnificent game. Indeed, it is hard to pick out a few for special mention, although the work of Coyne, Maynard, H. Cuntz, Maxfield and Kellogg was especially good.

The team was composed as follows: Coyne, goal; H. Cuntz, point; Martin, captain, cover point; Griswold, 1st defense; Maxfield, 2d defense; Klumpp, 3d defense; Corbett, center; Maynard, 3d attack; Kellogg, 2d attack; W. Cuntz, 1st attack; MacCord, outside home; Hutchinson, inside home; Willett, Patterson, Fielder and Ellsworth.

Below is a record of the games played:

Championship Series.

May 14, Stevens *vs.* Johns Hopkins, Hoboken; score, 4–3.
" 21, Lehigh " " " Lehigh; score, 8–3.
" 28, Stevens " Lehigh, Lehigh; score, 3–0.

Champions for 1892—Stevens; Lehigh, second, and Hopkins, last year's champions, third.

Practice Games.

April 15, Stevens *vs.* C. C. N. Y., Staten Island; score, 6–3.
May 4, " " Lawrenceville, Lawrenceville; score, 1–0.
" 10, " " Lorillards, Hoboken; score, 0–0.
" 18, " " Johns Hopkins, Philadelphia; score, 2–4.
" 25, " " Princeton, Hoboken; score, 6–0.

The second game with Johns Hopkins was an exhibition game played in Philadelphia at the American College Athletic Tournament, held by the Athletic Club of the Schuylkill Navy.

The "Annual Field Games" of the Stevens Institute Athletic Association were held on Friday, June 3, 1892. The weather was chilly and cloudy,

and there was a strong wind blowing which seriously interfered with the dashes, and base-ball and lacrosse throws, rendering it impossible to approach the old records. The grounds were in good condition, and the new grand-stand was filled with interested spectators. Two records were broken. Coleman, '94, broke his last year's record in the standing broad jump of 10 feet 1¼ inches with a jump of 10 feet 4½ inches. He also made a new record in the high kick—8 feet 6 inches.

The Committee on Games consisted of R. E. Hall, '94, H. F. Cuntz, '93, A. E. Merkel, '93.

The officers of the day were: Referee, J. H. Cuntz, '87; Timers, J. E. Doldt, O. A. C., Dr. F. L. Sevenoak, Prof. A. M. Mayer; Track Judges, K. L. Martin, '92, N. S. Hill, '92, M. E. Craft, '93; Field Judges, G. B. Fielder, '94, F. J. Angell, '94, G. P. Hodgman, '94; Starter, John Kyle, '93; Clerk of Course, A. E. Merkel, '93; Scorer and Announcer, F. D. Furman, '93.

Event.	First.	Second.	Third.	Time or Distance	Stevens Record.
100 yards dash.....	Maynard, '95.	Cuntz, '93.	Klumpp, '94.	11⅛ sec.	10⅛ sec.
220 yards dash.....	Maynard, '95.	Cuntz, '93.	Jewell, '95.	25⅘ sec.	24⅛ sec.
Quarter-mile run...	Cuntz, '93.	Klumpp, '94.	Kemble, '95.	58⅘ sec.	52⅘ sec.
Half mile run.....	Koehler, '95.	Siegfried, '95.	Corbin, '94.	2m., 21s.	2m., 14s.
Half-mile walk.....	Taff, '95.	Dear, '93.			
Three-legged race, 100 yards.....	Koehler, Hamilton, Jewell, '95	Stillwell, Greenidge, Maxfield, '95	Kollstede, Klumpp, '94	14 sec.	14 sec.
Relay race, 1 mile...	Siegfried, Kemble, Maynard, '95	Klumpp, Ellsworth, Snoemaker, '94	.....	4m., ⅛s.	3m., 50⅘s.
				Ft. In.	Ft. In.
Throwing base-ball.	Cuming, '95.	MacCord, '94.	Cooper, '95.	299 4	355 9½
Throwing lacrosse ball.....	MacCord, '94.	Corbett, '95.	Griswold, '93.	302 6	347 8
Standing broad jump.....	Coleman, '94.	Wood, '95.	Dear, '93.	10 4½	10 1⅔
Running broad jump.....	MacCord, '94.	Coleman, '94.	Kollstede, '94.	19 10	20 5½
Running high jump.	Coleman, '94, Corbett, '95.	Tied for first place.	Cuntz, '93.	5 2½	5 3⅔
Putting the shot.....	Lord, '93.	Coleman, '94.	Kemble, '95.	32 8	36 9
Throwing 16 pound hammer.....	Gallaher, '94.	Corbett, '95.	Coleman, '94.	64 9½	65 11
High kick.....	Coleman, '94.	Corbett, '95.	Cuntz, '93.	8 6	8 3⅔

Points scored—'93—20; '94—42½; '95—54½. '95 wins the banner offered by the *Stevens Life*.

BASE-BALL has had a hard time to keep in existence as a college sport this spring. The decision of the "Athletic Association" to withhold financial support from the team was a heavy blow. The adherents of the game soon rallied, however, and determined to support a team by subscription among the students and Alumni. In this they were successful, and a team was placed in the field which represented the college very creditably. Only a few games were played. There is only one point which seems to the INDICATOR to need criticism, and that is the practice of playing men who do not belong to the college. While it may be true that

there was no available man in college to fill the pitcher's position, and that the men selected from outside to fill that position added greatly to the strength of the team, still the practice savors strongly of professionalism, and must tend to weaken the support given to the game by the college at large. No man can take much pride in the victories of a team when he is obliged to remember that a large per cent. of the credit is due to players who have no connection with, or interest in, the college. If the game is to prosper, it must be carefully borne in mind that college sports are carried on by men who are at once amateurs and students, and that even the methods which custom has allowed to athletic clubs are here entirely out of place.

The following games were played:

May 4, Stevens *vs.* Rutgers, at Hoboken; score, 2–1.
" 19, " " New York University, at Hoboken; score, 25–1.
" 25, " " Rutgers, at New Brunswick; score, 6–1.
June 1, " " Jaspers, at Manhattanville; score, 5–13.

The team was composed of Cuming, catcher; Paulsen, 2d base; Decker, 1st base; Mackenzie, right field; Schalk, 3d base; Inglis, short stop; Strong, left field; Shiebler, center field; Corwin and Carniaux, pitchers; Weeks and Dear.

We quote the following editorial from the *Stevens Life*, because it is the most concise and forcible statement of an important matter, which we have yet seen. The questions raised here are bound to come up next fall with reference to the support of the foot-ball team, and we hope that every reader of the Indicator who is not a member of the association will give the arguments here advanced his careful attention:

"There has been some grumbling this season at the action of the board of the association in placing the price of admission to the games so high. This action was taken, not so much for the purpose of increasing the amount in the treasury, as it was to offer an inducement to joining the association. There are about 200 men in the college, and about 100 of these belong to the association, and by paying their dues help to support the teams. But the 100 not belonging to the association expect to enjoy the results of the work of the teams at the mere nominal price of admission to the grounds.

"This is not square at all, and those who derive the benefits at the least cost must be *made* to pay as much as the others, if they will not do so voluntarily. To do this it is necessary to make the total amount of admission to the games amount to more, if possible, than the dues of the association, and this is what has been the effort of the Executive Board.

"Of course there are some in college who cannot afford to pay the dues, and would rather pay admission at the grounds. But the interests of this few must be sacrificed to that of the large majority, for the sake of that majority, the teams and the Institute.

"It should be the aim and pride of every man in college to say that he belongs to the association, and has been a member since he entered the

Institute. The dues are ridiculously small, compared to those of other athletic associations or athletic clubs, and to the many benefits derived from being a member. This season the association was unable to support two teams, and the base-ball team was supported by contributions from undergraduates and the Alumni, through the courtesy of our professors, while the lacrosse team has only been able to get along by being very economical and saving. On this account has it been more desirous than ever to increase the membership, and for this reason was the price of admission placed higher. So far this has been a successful season, but the attendance at the games, though good, has not at any one time been as good as it was last spring. Join the association, every one, and show what college spirit can do in our small but enterprising college."

THE '94–'95 base-ball game resulted in an easy victory for '95. '94 was unable to hit Kemble, and '95 won as they pleased. Score, '94, 0; '95, 14.

THE Freshmen-Sophomore lacrosse game was forfeited by the Freshmen. This was a great disappointment to '94, as her strong team had been practicing faithfully, and hoped to make a large score to offset the defeat in base-ball.

THE lacrosse team has elected Hermann F. Cuntz, '93, captain for the coming year.

FRANK COYNE, '94, is captain of the foot-ball team.

THE tennis tournament resulted as follows: Class champions: '92, W. O. Ludlow; '93, Hermann F. Cuntz; '94, C. W. MacCord, Jr.; '95, Gurdon Maynard.

W. O. Ludlow, '92, retains the Institute championship.

QUITE a number of men were entered in the Intercollegiate Athletic games, but owing to the lacrosse game with Lehigh, on the same day, the only one able to take part was H. D. Coleman, Jr., '94, who represented the Institute very creditably in the running broad jump.

THE new grand-stand has already become popular, and has had a marked effect in increasing the number of ladies present at the games. It is a comfortable, commodious structure, with a seating capacity of about 250. It is situated in the northeast corner of the field near the base-ball diamond, and commands a fine view of the whole ground.

INSTITUTE NOTES.

PRESIDENT MORTON will spend the summer with his family on his estate at Pine Hill, in the Catskills.

PROFESSOR AND MRS. MAYER sailed for the Netherlands on the 18th of June. The Doctor will spend considerable time in Koenig's laboratory in Paris, continuing his experiments on the acoustical properties of aluminium, and may afterwards wander about the Continent, picking up valuable bits of scientific knowledge until it is time to return to the Institute.

DR. LEEDS will spend most of the summer with his family at Salisbury, Mass.

PROFESSOR JACOBUS attended the San Francisco meeting of the American Society of Mechanical Engineers, held on May 16. Besides reading a paper on "Summary of Results of Principal Experimental Measurements of Performance of Refrigerating Machines," he discussed numerous other papers presented, representing Stevens most ably. But his health failed in May, and with a party he indulged in an Alaskan trip. After that he made various excursions to the sights of the Western States, and returned East before the middle of July.

PROFESSOR DENTON has never before been so busy with his Department of Tests. The principal undertakings have been the test of the boiler plant of the Trenton Iron Works and tests for the Pintsch Lighting Company.

PROFESSOR MACCORD'S "Lessons in Mechanical Drawing" will appear in the early fall. It will be a collection of the articles which have appeared in the *Scientific American*, thoroughly revised, with about 200 illustrations.

THE *Link* OF '92 appeared a week before Commencement, and in wealth of excellent sketches and elaborate finish far surpasses any previous volume, though lacking in literary matter. In it all the class pictures, the lacrosse, foot-ball and base-ball team photographs, and those of the Glee and Banjo Clubs have appeared. Dedicated to the five Trustees, it contains on one of the front pages photographs of these gentlemen; but an excellent photograph of Prof. Albert M. Mayer occupies the first place.

The artists who have distinguished themselves are Litchfield, '92, Boody, '93, Merkel, '93, and Lawton, '94. Again the *Link* ranks first among college annuals. The editors are: Arthur E. Merkel, Franklin D. Furman, Herbert B. Cook, Adolph G. Hupfel, George L. Wall, Alfred B. Lord, Edward A. Huppertz, all of '93.

THE ENTRANCE EXAMINATIONS for applicants from the Stevens School were more difficult than usual in the different branches of mathematics. Consequently, not many more than 20 have passed without conditions, but at least 50 are expected to enter from that source.

THE STEVENS SKETCH CLUB is thriving, and no doubt caused the increase in standard of excellence of the work for the *Link*. Mr. D. C. Beard lectured before the club on Thursday afternoon, April 28, on "Sketching for Reproduction."

THE FIRST BROOKLYN CONCERT of the Glee and Banjo Clubs was given at Historical Hall on May 4. As in all this spring's concerts, success attended the efforts of Manager N. S. Hill, and the Stevens clubs acquitted themselves in a fashion which rivals the achievements of the musical talent of Yale and Princeton. Among 21 patronesses were noticeably Mrs. David A. Boody, Mrs. W. S. P. Prentice, Mrs. D. L. Braine, Mrs. A. Augustus Low, Mrs. I. A. Whitman and Mrs. William Rasmus.

THE GUN CLUB held its first shoot at the Cricket Grounds on Friday, May 27. The first prize, a handsome silver cup, was won by Coyne, '94, while Field, '94, won second place and a silver mug.

ON MAY 5 a meeting of those interested in tennis resulted in the organizing of the Stevens Institute Lawn Tennis Club, with the following officers: President, W. O. Ludlow, '92; Vice-President, B. G. Braine, '93; Secretary and Treasurer, E. B. Cook, '93. The organization will enroll "tennis fiends" and look out for their interests, greatly relieving the Athletic Association Board and simplifying matters.

THE HARTFORD INSPECTION TRIP was participated in by about 15 Juniors on May 17. The trip thither was made up the Sound by way of New Haven, and the rendezvous was at the Allyn House, Hartford. After inspecting the State Capitol the party's attention was directed to Pratt & Whitney's. When revived by a good meal at the Henblein House, steps were turned to the Colt Fire-arm Manufacturing Company, and after seeing many instructive and interesting things the Juniors with Professor Denton returned to Hoboken.

THE BETHLEHEM TRIP seemed more popular, for some 28 '93 men indulged in this. They left Friday morning, May 27, on a special car. At the Bethlehem Iron and Steel Works they were met by M. White, '79, and J. Danziger, '89, who showed the "inspectors" everything, beginning with Bessemer steel manufacture, and including the puddling process, the chemical laboratory and the Government works. After these investigations the game of base-ball between Lehigh and the University of Pennsylvania was witnessed.

The following afternoon these loyal Juniors met the Stevens lacrosse team at the station, and to their persistent and enthusiastic support during the great championship game, the victory over Lehigh is largely due.

CONTRIBUTIONS to the Alumni Building Fund will be deposited with the Hudson Trust and Savings Institution as they are received, and will draw interest until such time as they are needed.

INSTITUTE PERSONALS.

'76.

A. W. STAHL presented a paper on "The Utilization of the Power of Ocean Waves," before the San Francisco Meeting of the American Society of Mechanical Engineers.

WILLIAM KENT has an article in *Cassier's Magazine*, for June, 1892, on "Recent Changes in the Pig Iron Industry."

GUS. C. HENNING presented a paper at the San Francisco meeting of the American Society of Mechanical Engineers, on "The Elastic Curve and Treatment of Structural Steel."

'78.

ARTHUR A. DEBONNEVILLE is draughting for the Yale & Towne Manufacturing Company, Stamford, Conn.

'82.

EDMUND P. LORD is Superintendent of Motive Power of the C. C. C. & St. L. R. R., Cincinnati, O.

'83.

JAMES N. WARRINGTON went to Honolulu, Sandwich Islands, several months ago, for the benefit of his health, and expected to make an extended stay.

ARTHUR P. HENDERSON was married to Miss Grace McNair Briggs, daughter of Mr. and Mrs. Richard E Briggs, at St. Luke's Protestant Episcopal Church, Norfolk, Va., on Thursday, June 2.

JOSEPH E. STEWARD is Assistant Engineer of Signals, P., C. & St. L. R. R., Pittsburg, Pa.

'84.

WILLIAM S. ALDRICH had an article on "Designing Mechanical Movements" in the *American Machinist*, March 10, 1892. Before the Electrical Section of the Franklin Institute he read a paper "On the Variable Action of Two-Coil Solenoids," which appeared in the April number of the *Franklin Institute Journal*. A joint "Test of the Neversink Mountain Electric Road," Reading, Pa., made during August, 1891, with Mr. Herman S. Hering, Associate in Electrical Engineering at Johns Hopkins University, was published serially in the *Electrical World*, beginning May 28, 1892.

FRANK VAN VLECK contributed an illustrated article on "Track Brakes" to the *Street Railway Journal*, April, 1892.

DABNEY H. MAURY will be in New York shortly, *en route* for England. His temporary address will be in care Jones, French & Maury, 58 Exchange Place, New York City.

PRESCOTT BUSH is Master Mechanic of the P., C., C. & St. L. R'y at Columbus, O.

VICTOR MACKIEWICZ is with the Atlantic Refining Company, Philadelphia, Pa.

'85.

ARTHUR G. GLASGOW is now of the firm of Humphreys & Glasgow, gas engineers, London, England.

WILLIAM C. CORWIN is with The Nutley Electric Light, Heat and Power Company, 740 Broad Street, Newark, N. J. His permanent address is 253 Mount Pleasant Avenue, Newark, N. J.

H. J. BROADMEADOW sends his permanent address as Shrewsbury, Monmouth County, N. J.

BARTON H. COFFEY, on March 5 last, read a paper on the "Cost of Producing Power in the Internal Combustion Engine," before the Engineers' Club of Philadelphia, of which he is an active member.

'86.

W. R. KING has severed his connection with the Empire State Phosphate Company, and is coming North. Before departing from Ocala, in token of their esteem, the employees of the company presented Mr. King with a handsome silver service, and at the same time his wife was the recipient of a mosaic glass berry dish, mounted on silver, and various other articles presented by individuals. Mr. and Mrs. King have made many friends in Ocala and in Citrus County, who very much regret their departure.

HUMPHREY RUSSELL SMITH and Miss Rossannah Pitkin Gilman were married Thursday, June 30, at Colebrook, N. H. They will reside at 4469 Lake Avenue, Chicago, Ill., after September 15.

FREDERICK NASH MORTON was married to Miss Ellen Harwood Rich, on June 22, at St. Albans, Vt.

'87.

HERBERT A. WAGNER, who is Superintendent of the Missouri Electric Light and Power Company, has also begun to manufacture electrical apparatus and machinery under the name of the Wagner Electric Manufacturing Company, at 1822–24 Olive Street, St. Louis, Mo.

'88.

JOHN V. L. PIERSON is half-owner of the Foot Hill Nursery, Claremont, Cal.

'89.

D. H. GILDERSLEEVE is with the Archer Gas Fuel Company, 15 Johnson Street, Newark, N. J.

'90.

FRANCIS B. STEVENS, JR., has left the employ of the H. R. Worthington Company.

W. F. PHELPS is in business for himself, manufacturing electric fans in Dayton, O.

GEORGE WHITE MERRITT was married to Miss Mary E. Rider, on April 27, at Danbury, Conn.

'91.

JULIUS OELBERMANN was compelled to give up his position with Bement, Miles & Co., Philadelphia, on account of ill health. His address for the present is 115 North Sixteenth Street, Philadelphia, Pa.

CHARLES B. HODGES is in the Motive Power Department of the Cleveland, Cincinnati, Chicago and St. Louis Railway, Cincinnati, O.

GEO. L. MANNING has resigned his position as Instructor in Mathematics and Drawing at the Adelphi Academy, Brooklyn, N. Y.

PAUL SPENCER is Constructing Engineer for the Field Engineering Company, "Central Building," New York City.

LOUIS WALKER is draughting for the Baltimore Refining Company, Keyser Building, Baltimore, Md.

L. S. ATWATER returned from Germany the beginning of May, and proceeded to Pittsburg to superintend, for the Berlin firm with which he is engaged, the construction of a glass furnace.

'92.

JOHN TILSON SCHRAMME was married to Miss Frances Irene Sage, of Williamsbridge, N. Y., by the Rev. Charles A. Stoddard, on June 29.

HILL, VIDAL, WETTLAUFER, STRONG, MILLER, HOTOPP and WELLS were instructors in tests during Supplementary Term.

H. LOEWENHERZ has taken a position with the Missouri Electric Light and Power Company, American Central Building, St. Louis, Mo.

WILLIAM C. CUNTZ is located in the draughting room of the Bridge and Construction Department of the Pennsylvania Steel Company, Steelton, Pa. His address is P. O. Box 119, Harrisburg, Pa.

LUCAS FERNANDEZ has departed for his home, San José, Costa Rica.

LOUIS F. WETTLAUFER sailed on Saturday, July 9, for Europe, on his way to the Argentine Republic, where he will engage in engineering work.

HARRY D. REED is in the electrical testing department of the Bishop Gutta Percha Company, New York City.

AUGUST R. HAKE has a position in the N. Y. Central and Hudson River R. R. Co., and is at present working in the upper part of New York City, making preparations for the new bridge which is to cross the Harlem River.

'93.

G. C. MACKENZIE, ex-'93, finished a special course in architecture at Columbia in June, and will take up that profession in the fall.

GUS. ROELKER, ex-'93, has gone to South America as assayer to a mining company.

'94.

WILLIAM B. OSGOOD FIELD sailed by the "North German Lloyd" on June 18, and will spend most of his vacation in Bohemia.

GEORGE B. FIELDER will also spend his outing abroad.

HOWARD MAXFIELD will, voluntarily, repeat the Sophomore year, and it is to be hoped will gain time to develop into the greatest lacrosse player ever produced at Stevens.

BOOK NOTICES.

ACCESSIONS TO INSTITUTE LIBRARY, JANUARY 1 TO JUNE 30, 1892.

Books Purchased:

Engineering (*London*). Vol. LII.
Engineer (*London*). Vol. LXXII.
Electrician (*London*). Vol. XXVII.
Nature (*London*). Vol. XLIV.
Chemical News (*London*). Vol. LXIII.
American Journal of Science. Vols. XL., XLI., XLII.
Annalen der Physik und Chemie. Vols. XXXIX., XL., XLI., XLII., XLIII., XLIV.
Handwörter-buch der Chemie. Vol. V.
Railroad and Engineering Journal. 1890 and 1891.
Electrical World. Vol. XVIII.
Scientific American. Vol. LXV.
Scientific American Supplement. Vol. XXXII.
Dingler's Poly. Journal. Vols. 279, 280, 281, 282.
Journal für Chemie. Years, 1889, '90, '91.
Annales de Chimie et de Physik. Vols. XXII., XXIII., XXIV.
Franklin Institute Journal. Vols. CXXXI. and CXXXII.
Journal Chemical Industry. Vols. I. to X.
Manual Training. By C. M. Woodward.
Drainage and Sewerage of Dwellings. By W. P. Gerhard.
Tall Chimney Construction. By R. M. and F. J. Bancroft.
Compound Locomotives. By A. T. Woods.
Chemisch Technishe Analyse. By Dr. Jul. Post.
Chemists' Pocket-Book, 5th ed. By Thos. Bayles.
Brown's Assaying, 3d ed. By Walter Lee Brown.
The Marine Steam Engine, 3d ed. By R. Sennett.
Dynamo Electric Machines. By Carl Hering.
Hydraulic Motors, Turbine and Pressure Engines. By G. R. Bodmer.
Volumetric Analysis, 6th ed. By Francis Sutton.
Steam Heating for Buildings, 12th ed. By W. J. Baldwin.
The Steam Engine, 2d ed. By. J. H. Cotterill.
Absolute Measurements in Electricity and Magnetism. By Andrew Grey.
Water-Wheels. By M. Bresse
A Manual of Mining. By M. C. Ihlsing.
Specifications and Drawings of Patents. Parts 1 and 2, August to December, 1890.

Contributed:

By STEVENS INDICATOR: *Stevens Indicator*, Vol. XIII.
By American Society of Mechanical Engineers. *Transactions*, 1891.
By Professor Wood. *Hydraulic Motors.*
By Charles Pickering. *Chronological History of Planets.*
By Smithsonian Institute. *Catalogue of Prehistoric Works of the Rocky Mountains. Omaha and Ponka Letters.* Government Printing Office.
By Comptroller of the Currency. *Annual Report*, 1891.
By Commissioner of Patents. *Annual Report*, 1890.
By U S. Naval Observatory. *Washington Observations*, 1887.
By Treasury Department. *Annual Report of the Light-House Board to the Secretary of the Treasury. Report of the Treasurer on Finance.*
By Bureau of Education: *Graded Schools, Sanitary Condition, Higher Education in Indiana, Report of the Commissioners of Education*, 1888 *to* 90.
By Consuls of the U. S.: *Report on Commerce, Manufactories, etc.*
By Commissioners of Labor: *Cost of Production of Iron and Steel*, 1890.
By War Department: *Annual Report of the Chief of Engineers of the U. S. Army to the Secretary of War.*
By Interior Department: *U. S. Geographical and Geological Survey of the Rocky Mountain Region.*
By U. S. Light-House Board: *The Modern Light Service.*
By Department of Agriculture: *Experiment Station Record.* Vol. III., Nos. 4, 5, 6.

THE STEVENS INDICATOR.

VOL. IX. OCTOBER, 1892. NO. 4.

DETERMINATION OF THE BOILING POINT OF NITRO-BENZOL.

BY GEORGE L. MANNING, M. E., '91.

THE object of this investigation was to determine accurately, at ordinary atmospheric pressure, the temperature at which nitro-benzol boils.

The liquid is suggested as suitable for use in the standardization of thermometers, since it boils at about 216° C., is made in large quantities, and may be easily purified. This research is the first in a contemplated series, which has for its object the establishment of an exact scale of boiling points from 100° C. to 300° C. This scale would offer a ready means of correcting thermometers without recourse to the complicated air thermometer.

Nitro-benzol, before purification, is of a dark amber color, which becomes very light after repeated crystallizations and distillations. Its odor is much like that of bitter oil of almonds. It was discovered in 1843 by Mitscherlich, who found its specific gravity at 14°.4 C., to be 1.1866. It freezes in slender needles below 3° C., a circumstance of much value toward its purification. The sample used was made and very kindly furnished by Dr. Geyer. It was first purified by crystallization. A bottle containing about a litre of the liquid was surrounded with ice and allowed to stand in a cool place for two or three hours. At the end of that time the cork was removed and the bottle inverted, to

separate the crystals from the mother liquor. This process was employed six times. The liquid formed by melting these crystals was then filtered twice through bibulous paper, and distilled twice.

The distillation was carried on in a long-necked glass retort. From the side of the neck led a short inclined glass tube of small bore, which was inclosed by a larger tube 3 feet in length. This last tube formed the condensing part of the apparatus, and discharged into a bottle. No difficulty was experienced in condensing all the vapor within the length of this tube without the assistance of a water-jacket. Through the cork, sealing the neck of the retort, was passed a mercurial thermometer, whose bulb was suspended two inches above the surface of the liquid. This thermometer was merely intended to show whether the temperature of the vapor remained constant. It did remain constant, being 212° C. for two and one-half hours, during the first distillation, at an average pressure of 30.084 inches of mercury and an average atmospheric temperature of 63° F. During the second distillation it remained at 211° C. for three and one-half hours at an average pressure of 29.611 inches of mercury, and an average atmospheric temperature of 71° F. It will be noticed that this temperature of about 212° C. does not agree with the results of the experiments as deduced from the air thermometer. No mercurial thermometer can be trusted at so high a temperature without correction; and its readings may also vary according to the depth to which it is immersed in the vapor.

During the first half hour of ebullition vapor of water was disengaged, and very gradually the dense amber-colored vapor of nitro-benzol ascended and forced out the steam. While this lasted violent crackling took place from the explosion of drops of water which ran back at a temperature of about 100° C. into the boiling liquid whose temperature was about 216° C. It is possible, by a suitable regulation of the heating flame, to cause the vapor to condense at any height within several inches of the surface of the liquid. This phenomenon must be remembered when using the

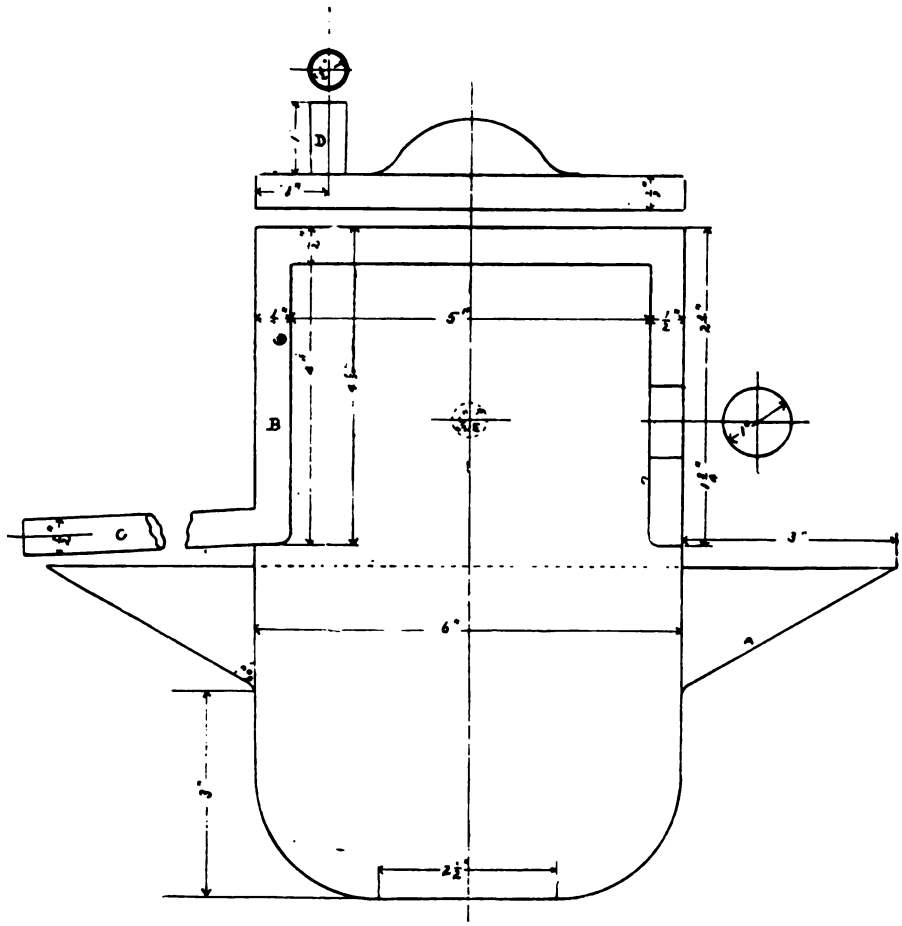


FIG. 1.

liquid with any thermometer, since it is quite possible that it might be boiling and yet not have sufficient heat to cause its vapor to ascend around the bulb of the thermometer.

Experiments proved that boiling nitro-benzol would corrode pure tin, melt solder, but would not affect copper. Wishing to use the air thermometer in the temperature determinations it was necessary to have a boiler whose joints were brazed. Fig. 1 gives the dimensions of a boiler designed by Professor Mayer, which was used with good results. It possesses some new features which deserve special notice. The outer flange marked *A* is intended to shield that portion of the boiler containing vapor, from the flame, thereby preventing superheating. The space marked *B*, between the inner and outer cylinders, forms a jacket from which the condensed vapor may run off by the tube *c*. This jacket insures the bulb being surrounded at all times by unchilled vapor. When in use a complete jacket of felt inclosed that portion of the boiler above the flange, as shown in Fig. 2. Through the cover of the boiler an opening *D*, Fig. 1., was made for the introduction of a mercurial thermometer, and also to enable liquid to be admitted after the cover was sealed down. The cover was sealed around its edge to prevent the escape of vapor. The cement used was made by mixing the white of an egg with slaked lime.

The opening at *E*, Fig. 1., was for the insertion of a U-shaped mercurial manometer, as shown in Fig. 2, to indicate any increase of pressure within the boiler.

The manometer column was so arranged that its right limb could be elevated to increase the pressure on the air contained in the bulb; and the observations were made on an apparently constant volume of air. The levels were read off by means of a nicely-adjusted cathetometer, made by Salleron, of Paris, and mounted on a slate pier, as shown in Fig. 2. This instrument noted accurately differences of the hundredths part of a millimeter.

The air of the bulb was exhausted thirty times, and dry air admitted over 5 feet of pumice stone, moistened with sulphuric

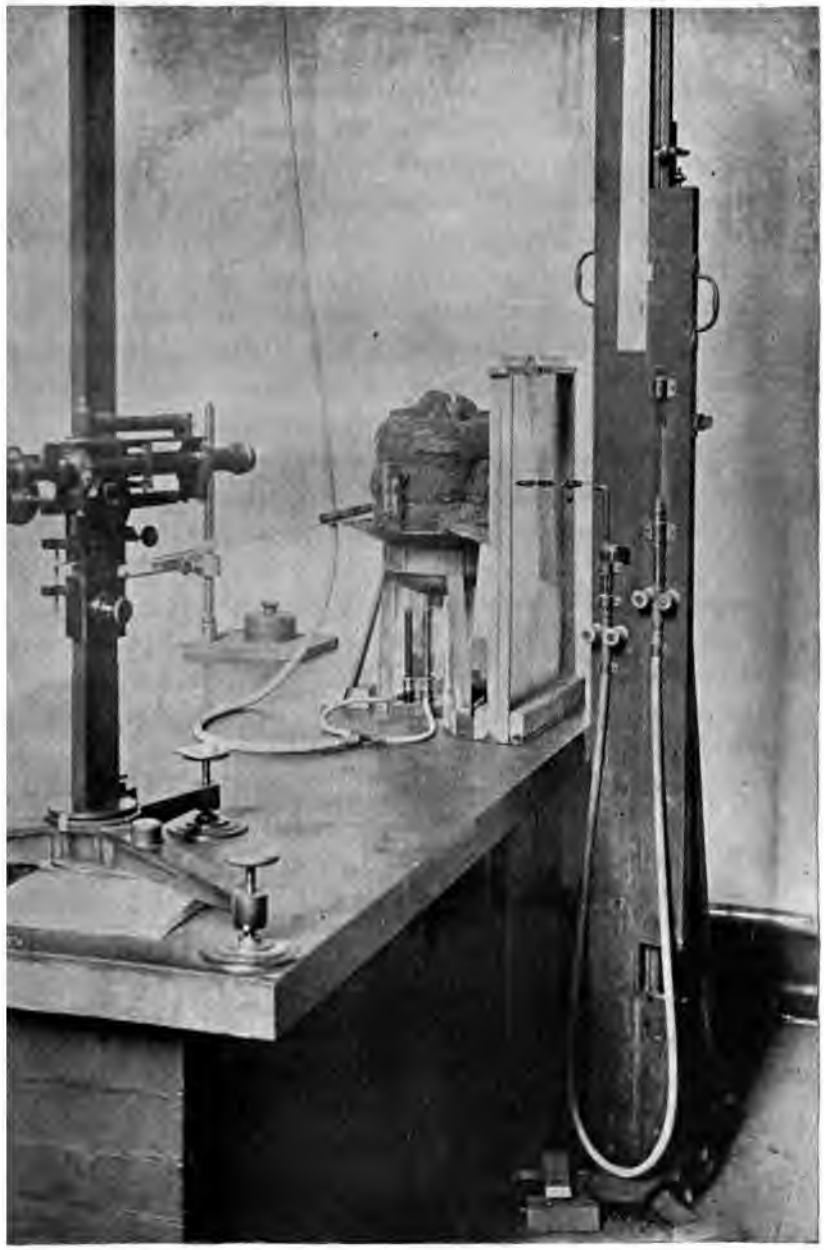


FIG. 2.

acid. All joints between the air bulb and manometer tube were sealed by means of a cement prepared from a receipt of Weinholdt's. Pure gutta-percha was melted in an equal volume of pure, black pine pitch, to which a very little resin was added to increase the firmness of the set. This cement, when hard, will resist strong pressure, and is yet somewhat elastic. It is easily dissolved by benzol.

The mercury used in the manometer was standardized, and found to have the correct density, 13.6. To insure its remaining clean after passing through the rubber tube, the latter was coated on the inside with thin shellac.

The bulb of the air thermometer was made of moderately heavy glass, whose co-efficient of cubical expansion was determined by means of a method devised by Professor Mayer, and described in Vol. XI., No. 238, of the *American Journal of Science.* The operation was performed as follows: The bulb was filled with distilled water by gradually heating it to expand the air within, and then allowing it to cool with its stem under water. The air within contracts on cooling, and water is drawn in. This operation was repeated several times, until the entire bulb and capillary tube were filled. It was then slowly cooled to 0° C. by immersion in cold water and finally in ice, and a mark was pasted on the stem to coincide with the meniscus and indicate a definite volume at that temperature. It was then slowly heated. The water in the bulb contracted until 4° C. was reached, after which it slowly expanded. When it reached the mark on the stem again it was kept at that point for half an hour by regulating the temperature of the water bath, and this temperature was carefully noted. It was found by a standard Baudin thermometer to be 11°.84 C. By reference to a very exact curve of the absolute expansion of water (drawn to the scale of 1 m.m. $= \frac{1}{100000}$ of unit of volume), and prepared by Rossetti, of Padua, the ordinate of 11°.84 C. was found to be .000306, which is the cubical expansion of glass caused by heating it from 0° C. to 11°.84 C. If .000306 be divided by

11.84, a quotient .0000258 is obtained, which indicates that the co-efficient of cubical expansion of the glass used was about .000026.

The volume of the bulb was determined by subtracting its weight when empty and dry from its weight when filled with distilled water at 0° C. The volume was found to be 425.821 c.c. By the use of the same principle, and the introduction of mercury instead of water, the volume of the connecting tubes between the stem of the glass bulb and the zero mark on the manometer limb was determined. This volume plus the volume of the bulb stem, from the inner edge of the cork which supported it in the boiler to its end, gave the true volume for which a correction of temperature was necessary. The principle of the air thermometer is based upon the assumption that all the air expands alike; but in this case it is evident that the air contained in the outside portion of the tube is subjected to a much less heat and consequent less expansion than the air within the bulb. The temperature was read at the neck of the bulb, and at the zero mark of the manometer each time an observation was made, because it was noticed that some heating of that portion of the neck between the boiler and the screen was unavoidable. In introducing this correction into the equation for temperature an average of the two readings was made as indicated by column 8 of Table I. The barometer and temperature of surrounding air were read at the beginning of each set of observations, and again at the end, the averages being entered in columns 9 and 10, respectively.

In mounting the apparatus it seemed necessary to introduce some flexible connection between the stem of the air bulb and the manometer column in order to insure safety against unequal expansion and possible cracking of the glass tubes. A very ingenious device of Professor Mayer's was employed here. It consisted of a capillary lead tube having at either end a collar, into which the bulb stem and manometer end were cemented.

PRELIMINARY OPERATION.

The bulb having been filled with dry air, and all connections sealed, the boiler was filled with ice, and after an interval of two hours the mercury in the manometer was carefully adjusted to the zero mark, and the reading of the cathetometer noted. The difference between the levels of the mercury in the two columns at this time gave the correction, when reduced to 0° C., which added to the reading of the barometer when reduced to 0° C. determined H_0 a constant of the temperature equation. It was discovered at this stage of the operation that when both bulb and manometer column were at the atmospheric temperature and pressure the level of the mercury in the two limbs of the manometer was not the same. The right hand column read .22 m.m. higher than the left hand column, indicating a difference in bore of the two tubes, and a consequent capillary depression in the left hand or smaller one. This minus correction is always to be applied to the reading of the pressure at any temperature.

FINAL OPERATION.

The boiler was supplied with 900 c.c. of nitro-benzol; the proper communications made with the condensing apparatus, and a small flame placed under the boiler. The liquid was very slowly brought to the boiling point in 75 minutes, and the manometer column carefully watched to regulate the pressure, so that an approximately constant volume of air might be maintained while heating up the liquid. When distillation was established at the rate of 14 c.c. a minute, as measured by a graduated receiving glass, and the pressure and temperature of the vapor, as noted by the mercurial thermometer within the boiler, were constant, a careful reading of the zero mark was made with the cathetometer, and the meniscus of the left or boiler side of the manometer column adjusted until it just bisected this mark. The telescope of the cathetometer was then raised, and the height of the right side of the mercury column carefully noted. A second observation on the zero mark completed

one series of readings. These checks on the zero point did not vary at all through the range of 10 observations.

THE FORMULA.

The formula used in calculating the temperature is one given by Kohlraush in his "Elements of Physical Measurements," and also by William Thomson in his "Physical Papers." As here used, the symbol K has been substituted for $3B$, to represent the cubical co-efficient of expansion of glass. The formula is as follows:

$$t = \frac{H - H_o}{A H_o - K H}\left(1 + \frac{V'}{V} \cdot \frac{H}{H_o} \cdot \frac{1}{1 + a\, t'}\right) \qquad \text{where}$$

t = temperature sought.

$H_o = b_o + h_o$ = observed barometer, plus the difference in levels of two mercury columns at time of 0° C. reading.

$H = b + h$ = observed barometer, plus difference in levels of two manometer columns at any temperature t.

a = co-efficient of expansion of dry air at 0° C. = .003665.

K = co-efficient of cubical expansion of glass used = .000026.

V' = volume of air in outside tube = .1724 c c.

V = volume of air in bulb within boiler = 425.649 c.c.

t' = average of temperature at neck and at zero mark of manometer.

In the following table will be found the resumé of the tests made, giving as the boiling point of nitro-benzol 216°.452 C., which is the average of two determinations.

TABLE I.

$H_o = 762.92$ m.m.; $aH_o = 2.796$;
$V = 425.649$; $V' = 1.2433$; $a = .003'65$;
$K = .000026$; $\frac{V'}{V} = .00292$;
Capillarity $= -.22$ m.m

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Constants.	Zero Reading. Left Side.	Right Side.	Average Difference of 2 and 3.	4 at Zero and Corrected for Capillarity.	Average Temp. at Manometer.	Average Temp. at Neck.	Average of 6 and 7 $t'' = \frac{t'' - t'''}{8} + t''$	Average Barometer.	Average Temp. at Barometer.	Barometer at 0° C.	$11 + 5 = H$	$H - H_o$	$\frac{H}{H_o}$	KH	$\frac{1}{1 + at'}$	t	Differences from Mean
First Set of Observations.	51.32	650.76															
	51.32	649.80															
	51.32	649.76															
	51.30	649.65															
	51.38	651.54															
	51.35	651.52															
	51.32	650.60															
	51.32	650.56															
	51.30	650.60															
	51.30	650.60															
	51.32	650.80															
	51.30	650.82															
	51.32	650.82															
	51.32	650.90															
	51.34	651.00															
	51.28	650.84	599.34	596.74	24°.6C.	38°.8C.	26°.38 C.	764.30	24°.25C.	761.305	1358.045	595.125	1.780	.0353	.9118	216°.567 C.	.114
Second Set of Observations.	51.40	650.04															
	51.39	650.12															
	51.32	650.14															
	51.32	650.00															
	51.30	650.10															
	51.28	650.04															
	51.26	650.06															
	51.26	650.02															
	51.26	650.06															
	51.28	650.12	598.757	596.16	24°.6C.	38°.5C.	26°.34 C.	764.25	24°.25C.	761.255	1357.413	594.493	1.779	.0353	.9119	216°.338 C.	

THE MECHANICAL AERATION OF WATER.

BY PROF. ALBERT R. LEEDS, PH. D.

THE author has been repeatedly asked to give some account of the mechanical aeration of water, and will take this opportunity of so doing in the columns of the INDICATOR. This journal is the most appropriate place of publication, for the reason that the first experiments (which were tentative and preliminary in their character) were made in the chemical laboratory of the Institute, and the favorable results obtained from them led to the introduction of mechanical aeration into engineering practice.

The experiments alluded to grew out of an experience which the city of Philadelphia encountered, during the winter and spring of 1883, in connection with its water supply. The eastern part of this city was supplied with water pumped from the river Delaware, and the western part with water taken at Roxborough, Belmont, Spring Garden and Fairmount pumping stations, from the river Schuylkill. The Schuylkill supply, at the date referred to, became very offensive to taste and smell. My duties as chemist to the Water Department requiring that I should ascertain the origin of these tastes and odors, I made a somewhat prolonged investigation, in the course of which were elicited the following curious facts.

The worst water was that supplied at the Spring Garden and Fairmount pumping stations. These are located in the Park, a strip of land running up from Fairmount along the Schuylkill River a number of miles to Wissahickon Creek, and purchased by the city of Philadelphia, ostensibly not so much for a pleasure ground as for the purpose of protecting the purity of its water supply, and in order to get rid of the factories, etc., along the river banks. Among the buildings thus removed were many ice houses, and with their removal the water no longer had opportunity, in freezing weather, to come into contact with the air. Moreover, the winter

referred to was unusually severe, and the ice coating was unbroken for 90 miles of flow. The river during its course had received more or less of the sewage of many manufacturing towns, and the analyses revealed that this sewage was in a condition of putrefactive decomposition. More especially this was shown by the deficiency of dissolved oxygen in the water, the oxygen having been partly consumed in the oxidation of the sewage, and the supply of the atmospheric air having been cut off by the unbroken coat of ice. I pointed out that whereas sewage in presence of oxygen is oxidized to harmless products like carbonic and nitric acids, water and ammonia; it undergoes putrefactive changes when air is excluded, and yields foul smelling gases, like sulphuretted hydrogen, or combustible gases, like carburetted hydrogen. In fact, the latter were found in such quantity, that it was a common experiment to cut holes in the ice above Fairmount Forebay and set fire to the escaping gases.

In the endeavor to account for the observed facts, and more especially after analysis had revealed the disappearance of oxygen and its replacement by the gaseous products of putrefaction, I was led to experiment upon what would take place were these abnormal conditions reversed and the water brought back into a normal condition, as to exposure to light, movement and oxygen. On analyzing some of the same water, after it had been agitated for a number of hours in contact with air which had been carefully purified, I found that it had entirely lost its offensive taste and odor; its percentage of oxygen had risen to its full capacity, and its oxidizable organic matters had been reduced. I then submitted these results to Messrs. Cheeseborough, Vaughn Merrick and Gräff, the members of the special Water Commission at that time, and to Col. William Ludlow, Engineer-in-Chief, and proposed that all this offensive water should be purified by aeration under pressure in the rising mains. While much interested in the proposition, these gentlemen pointed out that it was entirely novel to them, and a very considerable responsibility would be incurred in carrying it into

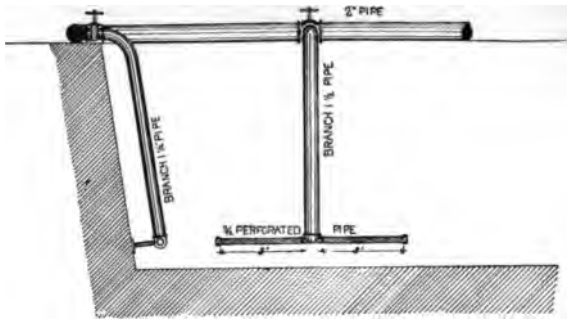
practical effect. Though the actual test on a large scale was thus delayed, I thought it very probable that it would come to pass later on, after such test had been made, that everyone (and such has been the case) would say that there was no merit and novelty in the proposition, and that the same thing had been done before the Flood. Therefore, I patented the process.

Subsequently, the Chief Engineer attached an air pump to the 48-inch main of the Spring Garden station, and the results of aerating the water in a column of 3,000 feet in length being satisfactory, he applied the process generally. But the pipes for distribution were at many points very old, and the fear of leakage caused the experiment to be discontinued.

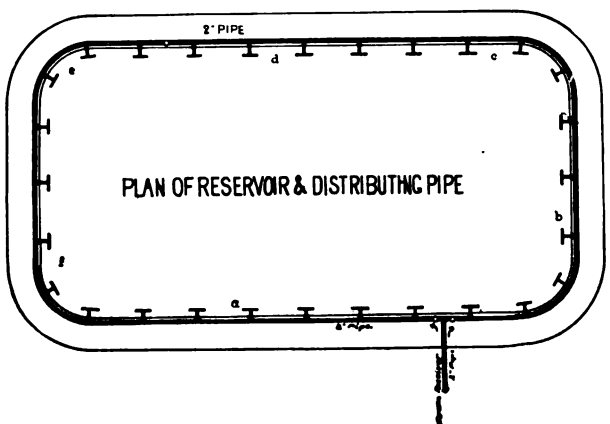
A fortunate catastrophe occurred while matters were in this stage, which at once brought the aeration of water supplies by mechanical means into large use. The summer of 1884 was at times unusually warm, and during one of the hottest periods the water of Hoboken suddenly acquired a most pronounced, and to many persons a very unpleasant, vegetal odor and taste. The drainage area of the Hackensack River, from which the supply is taken, was found to be without any similarly affected waters, and the trouble was located in the distributing reservoir water itself. This holds 15,000,000 gallons, and during less than 24 hours the previously clear water became covered with a thick coat of bluish-green algæ. I proposed, as the cheapest and most effective remedy, that an air-compressor should be attached to the 30-inch main at New Milford.

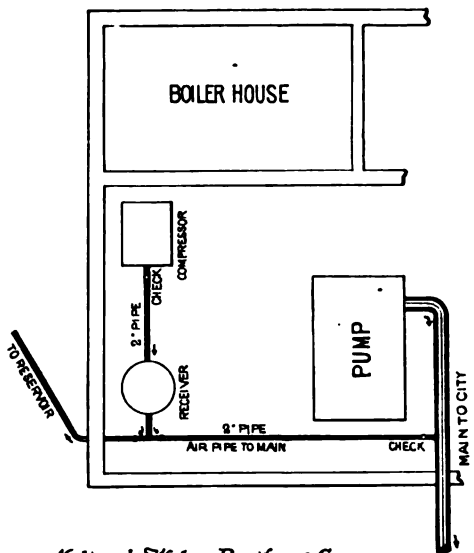
The air driven into the water would thus have an opportunity to act upon it during its flow of more than 17 miles, over two summits and through two submergences of the pipe, and finally would escape as the water flowed into the reservoir placed at considerably more than 100 feet elevation above New Milford.

Some distinguished hydraulic engineers predicted failure on the ground that the air would fill the summits, and would act as a cushion against which the water might be pumped without advancing further in the main. But with the least possible delay, Mr.



Detail of Branch Pipes & Air-rose.





National Water Purifying Co.

Plant for Aeration of Reservoir and Mains

Norfolk Va. *June 5th 1900*

Branches from a to b - 2½"
" - b to c, y a to f - 1"
" - c to d, g f to e - 1¼"
" - c to d - 1½"

All branches to be furnished with Valves.

Chas. E. Brush, the Chief Engineer, began the aeration. The growth of algæ ceased immediately and the water was restored to its usual palatable condition. During the eight years that have elapsed, the trouble of either air-cushions or air-leaks in the main or distribution service has never occurred. It is true that the water drawn from the service pipes, sometimes is milky from the great number of air-bells diffused through it. This appearance was at first attributed to "sewage," and in a recent publication in an engineering magazine, to witchcraft, but the consumers soon learned to relish and appreciate the liveliness and palatibility of such highly aerated water. There has been no evidence or complaint of its action upon lead or iron pipes, or of its occasioning trouble or corrosion in boilers.

After this process of aeration had been in use for three years, a season of prolonged heat during the summer of 1886 brought about the formation of patches of algæ in the corners of the distributing reservoir. The water, as it flowed through the inlet pipe, contained its normal percentage of dissolved oxygen and carbonic acid. But on standing, it quickly lost the former and increased the latter, and the phenomena of stagnation made their appearance. Mr. Brush then applied another patented feature of my aeration system, which is the driving in of air through a pipe carried around the four sides of the reservoir and terminating in many rose-jets placed at the ends of terminals going down nearly to the bottom. The air boils up at any or all of these points through the water, and the breaking up and disappearance of patches of algæ take place forthwith. Each month an analysis of the water (including a determination of dissolved oxygen, carbonic acid and nitrogen), has been made of samples taken from the pump-well, the reservoir and the distribution system. They show the beneficial effect of this system and the entire avoidance of the trouble, which it was introduced to remedy, during this period.

Subsequently the National Water Purifying Company, of New York, which had acquired my patents, applied the system in many

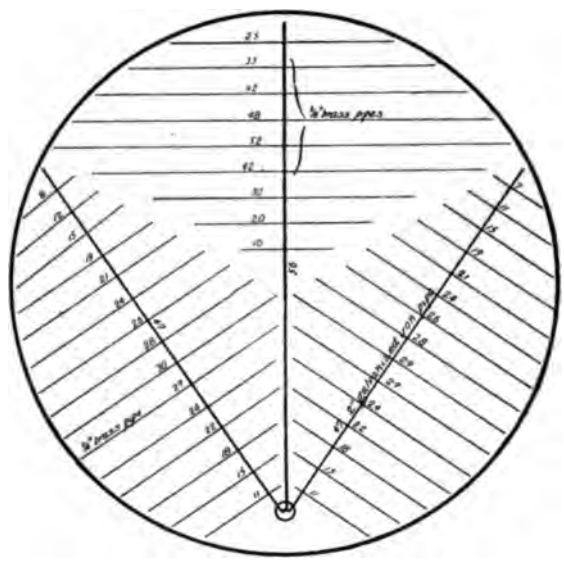
places. At Norfolk, Va., for instance, aeration both in the pipes and in the reservoir was resorted to. A diagram of the Norfolk installation is inserted and can be understood without further description. Later on these patents, together with those of the Hyatt Pure Water Company, became the property of the New York Filter Company. They include the method in use at Long Branch, N. J. Like Norfolk, the water supply of this place is deeply colored with peat. It is aerated by being made to fall through a pipe sunk in a well of 100 feet depth, the circular weir over which it flows being depressed below the mouth of the pipe. A funnel-shaped whirlpool is thus formed which carries down the air. The excess of air passes off in the pump-well.

Still another modification of the system is employed at New Rochelle, in the vicinity of New York. The water is impounded in a reservoir at a higher level, and flows down from this for a distance of about a mile and a half to a second storage reservoir. Some short way below the first reservoir a water motor is located, which drives an air compressor delivering air into the same main that supplies water to run the motor. Part of the air is carried down the main and the excess escapes with the water at the lower reservoir: another part forces its way up and escapes into the upper reservoir after traversing about 300 feet of descending water. In addition to the aeration thereby effected, the water from the lower reservoir is pumped into a stand-pipe to a higher level than that in the water tower and falls into the latter in an umbrella-shaped fountain passing as a thin sheet through many feet of air. All the water not used in the high service, is returned to the first reservoir and thus again repeatedly aerated in the descending main. The difficulty previously encountered, arising from offensive taste and odors, has not been experienced since the installation of the aerating process above described.

At the present time, a suitable provision for mechanical aeration has come to be a recognized feature of a properly arranged system of storage and distribution reservoirs and pipes. In a recent

report to the Albany Water Commission, the eminent hydraulic engineer, Mr. Alphonse Fteley, recommended that their impounded waters should thus be kept sweet and lively. The great Quaker Dam reservoir of the Croton water-shed, which is to hold 3,000 million gallons, will require its application.

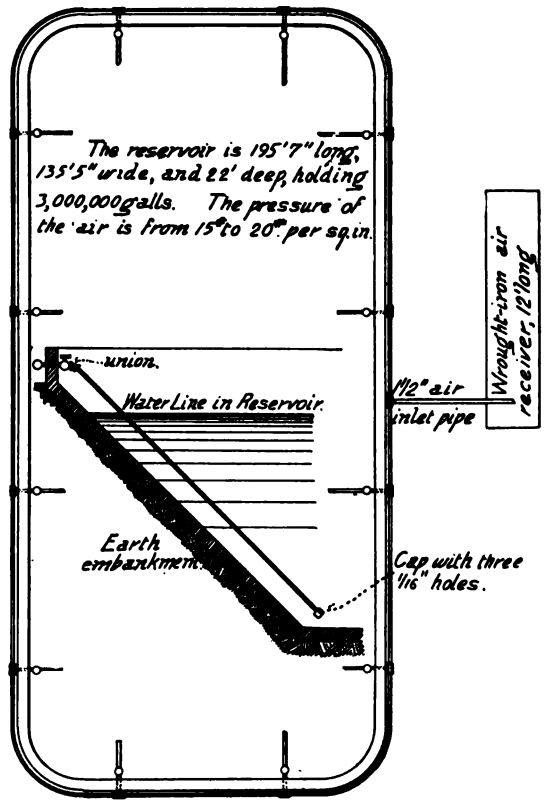
Mr. Worthen strenuously opposed the building of a reservoir whose capacity was so great in comparison with the inflow and outflow, on the ground that *stagnant water will not keep.* But in prop-



erly aerated water the conditions which accompany stagnation do not exist, and when this practice of aeration has become universal in hydraulic engineering, the annually recurring sicknesses, that water is subjected to when unnaturally impounded in ponds, lakes, reservoirs and pipes of our present water supply systems, will disappear.

In the spring of 1891 the well-known consulting hydraulic engineer, Mr. Phinehas Ball, of Worcester, came to the Institute with an interesting account of the troubles experienced at Brockton, Mass., from disagreeable odors and tastes arising from growths in

the reservoir. He desired to know whether they were of such a nature as would be remediable by aeration, and being able from his description to assure him that they could be so cured, his clients, at


The reservoir is 195'7" long, 135'5" wide, and 22' deep, holding 3,000,000 galls. The pressure of the air is from 15 lbs to 20 lbs per sq in.
union.
Water Line in Reservoir.
1/2" air inlet pipe
Wrought-iron air receiver, 12' long
Earth embankment
Cap with three 1/16" holes.

his recommendation, purchased the right of employing the process, and put in the aerating system according to Mr. Ball's working plans. The reservoir is a steel tank, 62 feet in diameter and 59 feet high, holding 1,300,000 gallons. Three 2-inch galvanized iron pipes, radiating from a point near the side, are placed at the bottom of the tank.

The two side arms are 47 feet, and the center arm is 56 feet ;. The latter bears five radial brass pipes three-eighths inch

diameter, and in addition are 39 one-quarter inch pipes, arranged as shown in the cut.

The perforations of the radials are one-seventh inch, placed three feet apart. The 2-inch pipes are furnished with air-valves and are branched into the supply pipe, which is controlled by a check-valve to prevent backward flow into pump. A 7½″x9″x9″ Clayton duplex compressor is used, supplying 172,000 cubic feet of air per 24 hours. According to the statements of the Superintendent, W. F. Cleaveland, the aeration of the water in the tank, as above described, has greatly improved its quality and potability.

Another aerating plant, similar in its general features to those of Hoboken and Norfolk, has recently been installed at Charleston, S. C., under the superintendency of C. A. Chisolm. The aerating reservoir holds 3,000,000 gallons and is 195′ 7″ long, 135′ 5″ wide and 22 feet deep. The air under a pressure of from 15 to 20 pounds to the square inch issues out of caps placed on the ends of 12 pipes terminating at the sides of the reservoir near the bottom. These branch pipes connect at top with a main 1½ inches in diameter. The latter is not connected with the compressor, but with a 12′x20″ wrought-iron receiver. The air is supplied by a Blake compressor with cylinder 6-inch diameter and 10-inch stroke.

In a subsequent paper I shall give the eudiometric methods for the determination of the dissolved oxygen, carbonic acid and nitrogen which I have employed, but as yet have not had leisure to publish. Also the chemical and physical changes produced by aeration and the conditions under which its action is most beneficial.

DEVELOPMENT OF THE SMOKE-BOX OF THE LOCOMOTIVE.*

BY WM. A. FIELD, M. E., '91, AND JAS. T. WALLIS, M. E., '91.

IN selecting the development of the Locomotive Smoke-Box as the subject of our thesis, we have done so for the reason that in this country at least, it has received comparatively little theoretical consideration, and is perhaps the point that is the least defensible in our modern locomotive practice. Our idea is to review early foreign and domestic practice, to trace the gradual development of the same into the standards of to-day and to point out in what particular this practice is defective. We will also try to show the direction in which improvement may be made by discussing the subject theoretically, and by proving the discussion by the actual peformance of locomotives under different conditions. We intend to confine ourselves especially to the Smoke-Box and such other parts as are allied to it. By the term "Smoke-Box" we mean to include the chamber in front of the tubes in which are the exhaust nozzles, diaphragm, netting and stack. These parts depend more or less on each other, and it is to ascertain the most advantageous proportions and relations of these to each other that this paper has been written.

Prior to 1804 the necessity of forced draught had not been felt. About this time Mr. Trevithick suggested the idea of exhausting into the stack, and he has the credit of being the first to propose this plan. In 1815 he proposed two methods for forced draught—by fans and blowers. The former, however, had been anticipated, in 1812, by the Chapmans, who included it in their patents. But little improvement was made in producing forced draught until it became a necessity in the locomotive boiler, about 1825. In 1827 Mr. Timothy Hackworth made, it is said, the first successful application of the blast pipe to a locomotive.

* Abstract of Graduating Thesis.

Previous to 1829 the engines on the Killingworth Railway exhausted into the stack, built in compliance with Stephenson's ideas put forth in 1825 or thereabouts. The blast, however, in these engines was not considered an essential feature. Indeed, from the writings of Mr. Wood in 1825, it appears that this gentleman regarded the blast as an accidental circumstance, and considering that it wasted fuel as well as promoted combustion, replaced it by an enlargement of the flue area.

In 1829 two locomotives of the Stephenson type were sent to France to be used on the Lyons and St. Etienne Railway. M. Seguin, engineer for the road, wishing to increase their speed, saw the necessity of increasing their evaporative power. This led to the application of a previous invention of his own, namely, the tubular boiler (1827). With the increase in evaporative power came the necessity of a greater draught, to accomplish which purpose he at first used a circular fan, but M. Pelletan solved the problem by the introduction of a jet into the stack. From this time little change was made in the exhaust pipes and nozzles. Every new locomotive built had nozzles adapted to the special construction of the engine without any difference in principle. Each particular style of exhaust proved amply satisfactory for the duty imposed upon it, and the improvements made in the locomotive were largely confined to perfecting the mechanism. It was not until comparatively recently that any special attention was paid in this country to the front end of the locomotive.

In 1867 the Pennsylvania Railroad adopted the diamond stack as standard for all classes of locomotives.

A description of this stack is hardly necessary. It is shown in Fig. 1, page 320, where *N* is the nozzle, varying in height from 7 to 10 inches; *L* is a lift pipe, a sheet iron funnel about 1 foot in diameter, capable of adjustment in height with reference to the nozzle and base of the stack. Its office was to equalize the draught, to contain the exhaust steam from the nozzle and direct its course to the stack and to keep the smoke-box clear of cinders; *D* is a deflector

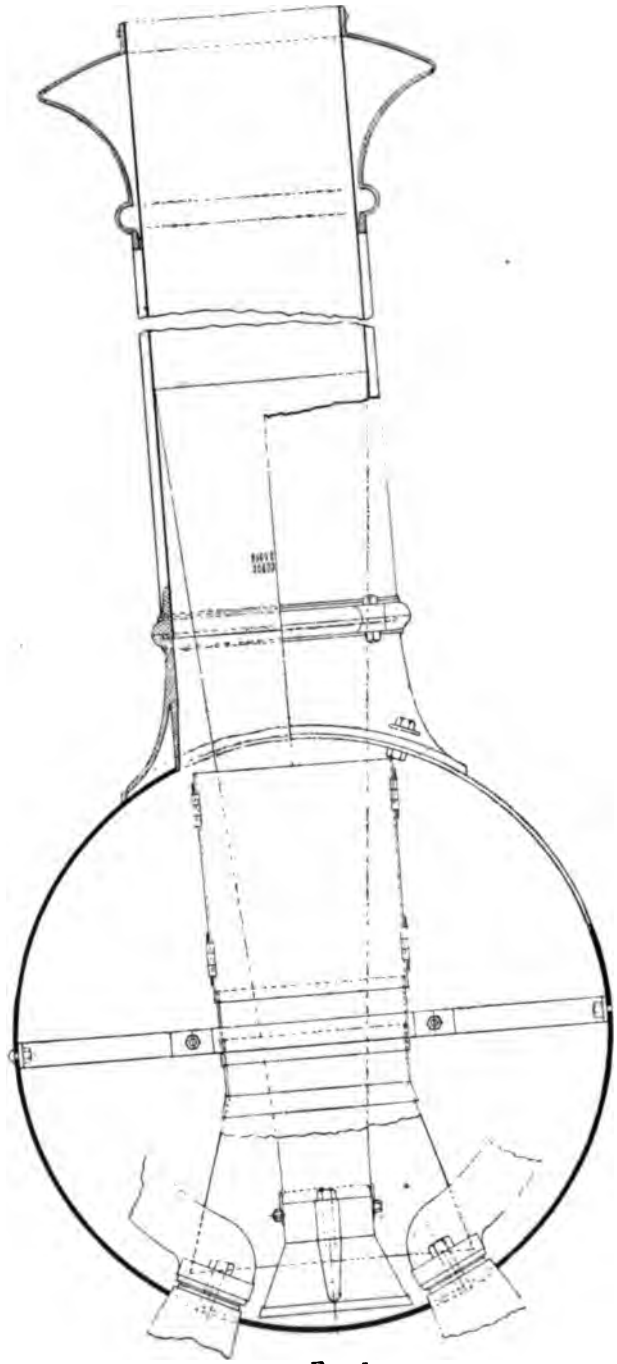


FIG. 1.

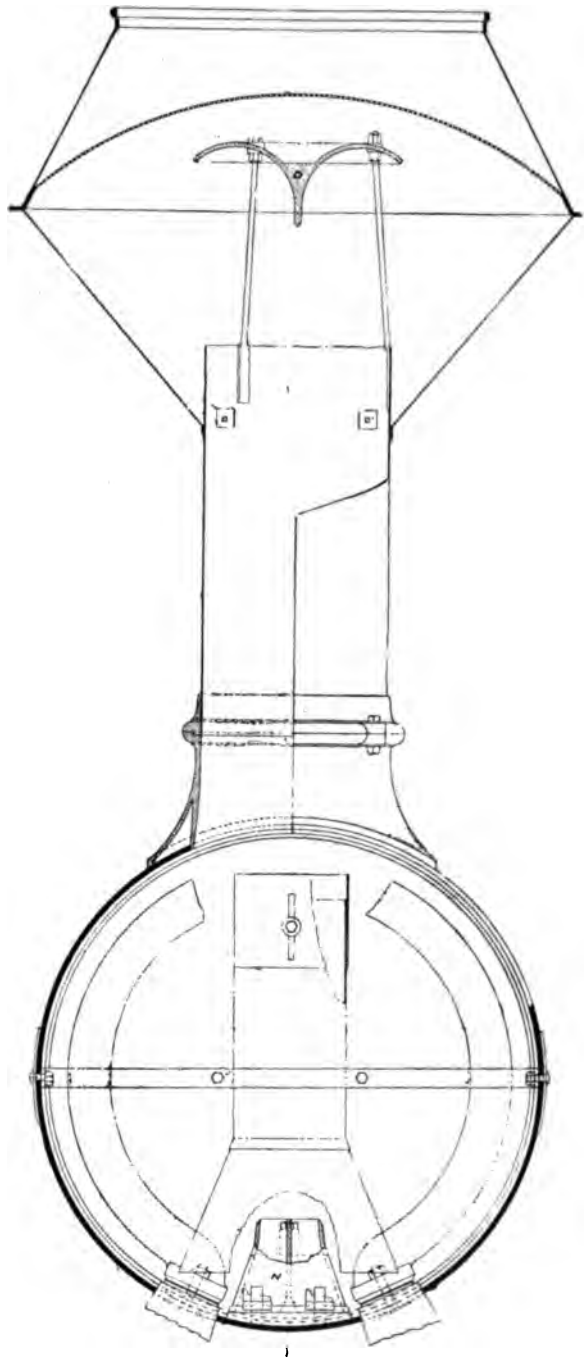


FIG. 2.

which turns the course of large cinders, causing them to fall back into the stack through the orifices *O O'*, (of which there are four), to be again thrown against the deflector, broken up and extinguished. By this battering process they are soon reduced to a size capable of passing through the wire screen *S*, and are thrown out of the stack.

The Diamond was the standard stack for many years and is still in successful use in freight service.

Then the Smith Spark-Arrester became standard for passenger locomotives. See Fig. 2, page 321. The nozzle and lift pipe are the same as in the diamond stack, but the stack proper is straight. The screen or arrester in this arrangement is a cone *c* fastened at the top of the nozzle and extending about two-thirds up the stack. This cone is perforated with 1 x ¼-inch slots, *b*. Very good results were obtained from this stack, but for very high speed it choked up with cinders until the firemen began to cut holes in the netting close down to the nozzle. This produced better steaming results, but caused showers of sparks to be projected from the stack, resulting in inconvenience to passengers besides suits for damages by fire to property adjoining the railroad.

Something had to be done to prevent this loss of property and also insure good steaming qualities in the locomotive. At last, early in 1880, the first part of the problem was solved by the addition of a cylindrical extension in front of the smoke-box proper and called the extended front. This, while theoretically incorrect from the fact that it increased the size of the smoke-box, enabled the cinders to be retained to be blown out at the end of each trip.

The wire screen or netting had to be placed above the top row of flues as shown, in order to arrest sparks effectually. A higher nozzle than heretofore used had to be employed, and it was at this time that the question arose, and is still the subject of discussion, as to what style of nozzle would give the best results, the single or double. The conditions that must be fulfilled by a successful and desirable nozzle are:

That it must create draught enough on the fire to make steam and at the same time impose the least possible amount of work on the pistons in the shape of back pressure.

It should be large enough to produce a nearly uniform blast without lifting or tearing the fire, and be economical in its use of fuel.

As the single orifice nozzle permits the use of a larger opening, the back pressure is necessarily less, and it becomes important to determine just how far up in the single pipe, the bridge, separating the two cylinders, shall go. This seems to be entirely a question of design, and it is difficult to determine from cards alone, taken with a round nozzle, whether the bridge is high or low.

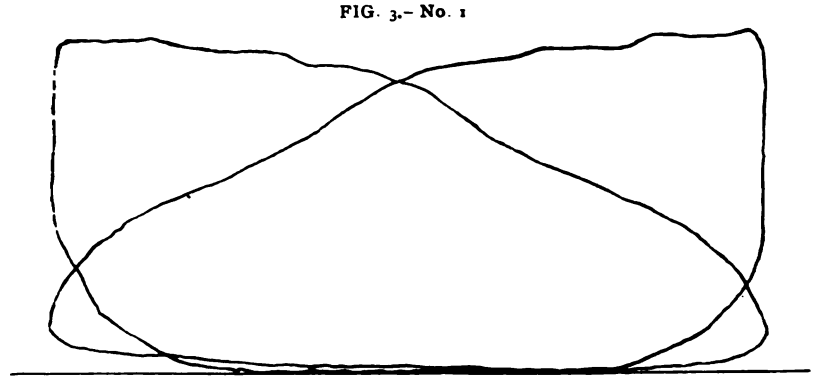
As before stated, the principal division of opinion is on the relative advantages of the single and the double nozzles.

The advocates of the double pipe claim that this is the only arrangement by which the exhaust from one cylinder is prevented from producing back pressure in the other. On the other hand, the upholders of the single nozzle argue that the use of two openings prevents either of them being central with the stack, and in consequence the exhaust will not produce the maximum effect.

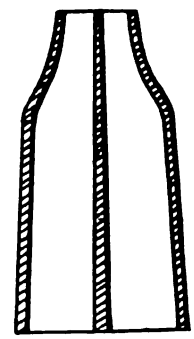
The single exit being in the axis of the stack will produce the maximum effect, and can in consequence be made larger and reduce the back pressure.

In 1882 the Pennsylvania Railroad made a series of experiments to determine which form of nozzle should be adopted as the standard. Four styles of nozzles were used in the test. No. 1, Fig. 3, page 324, is a double nozzle with openings 3½x2¾ inches. Here it is seen that the bridge extended quite to the top and gave a reasonably good card. In No. 2, Fig. 3, the nozzle is rectangular at the base merging into a cylindrical tip 4⅝ inches in diameter. The height of the bridge is a little over half the height of the nozzle. This type gave an average back pressure of four pounds. The cards taken with this nozzle show a decided hump due to the steam passing from one side of the bridge and interfering with the free exhaust from

FIG. 3.– No. 1

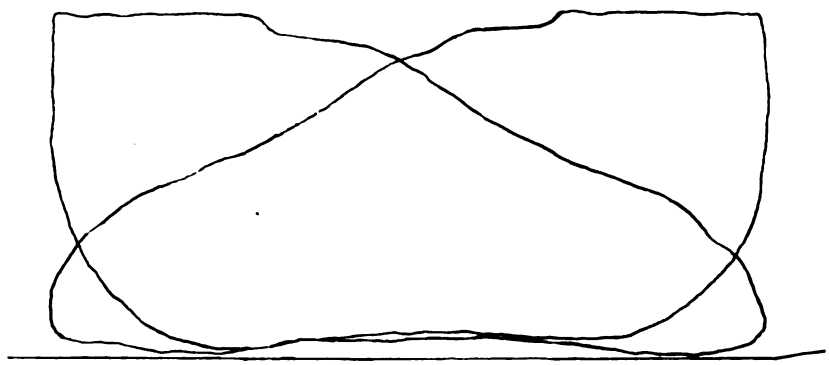


3½x2¾-INCH.

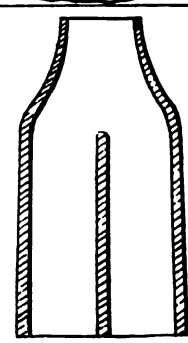


Boiler Pressure. . . .	121
Revolutions Per Minute. .	115
Revolutions Lever Notch. .	9
Throttle Notch. . . .	6
Spring.	60

No. 2.



4⅝-INCH DIAM.



Boiler Pressure. . . .	123
Revolutions Per Minute. .	113
Revolutions Lever Notch. .	9
Throttle Notch. . . .	6
Spring.	60

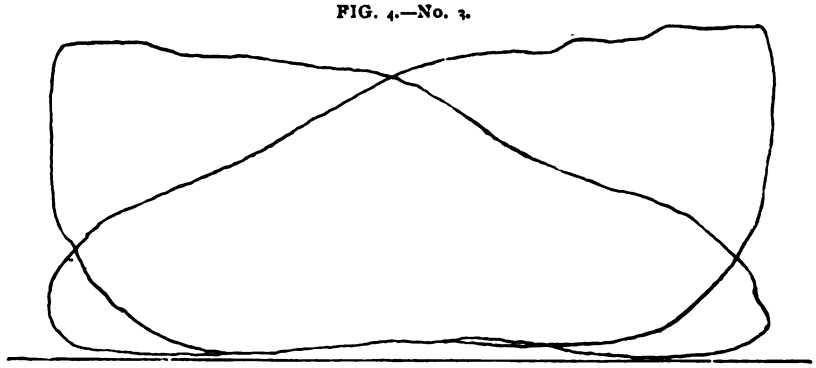
the other cylinder. This is the result of having the opening at the tip less than the opening at the bridge. No. 3, page 326, is the same as No 2, with the exception that the bridge is very low in comparison to the height of the nozzle. The average back pressure was 4½ pounds. This nozzle is defective for the same reason given in the previous case, and besides all the space between the bridge and nozzle tip being a reservoir from which steam escaped through the tip and into the opposite cylinder. From these very incomplete experiments it was decided that the single nozzle could never be made to show the results obtained in the fourth case, Fig. 4, where a double nozzle with 3½x2¾-inch openings was made. Of the four nozzles tried the best result, as far as back pressure is concerned, was obtained from No. 4, which gave an average back pressure of two pounds. The result of these experiments led to the adoption of the double nozzle as standard. It was not long, however, before it was proved that the standard nozzle had to be made very small to give good steaming results.

Since the time of these experiments many devices have been looked into with the view of getting larger nozzles and consequently less back pressure. Among others was the variable exhaust which allowed the size of the nozzle-opening to be decreased or increased as the demand for steam varied. This nozzle was unsuccessful because of its clogging with cinders. The Smith Exhaust was also examined, and while it gave fairly successful results, so far as steaming was concerned, it was bulky and expensive and in no way reduced the back pressure. It was a series of ejectors, and is shown on page 327. The results of the test, with the best and worst cards, are given on pages 328, 330 and 331.

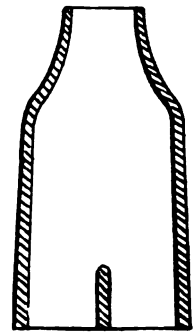
At the same time three other nozzles were tested, a comparison of the results being given on page 329. The 3½x3¼-inch nozzle proved itself the best for a certain engine, but no important deductions were made from the results of the test.

Little change, therefore, for the good had been accomplished, and no attempt was made to find out the relations of the stack and

FIG. 4.—No. 3.

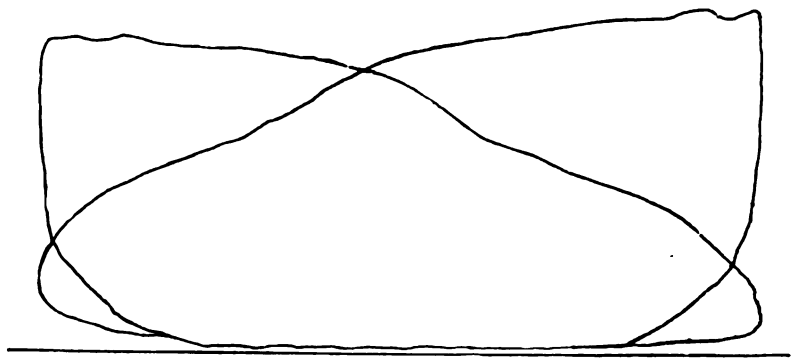


4⅝-INCH DIAM.

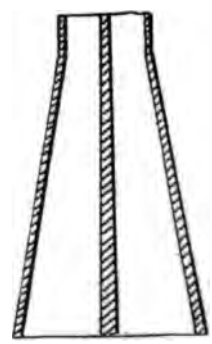


Boiler Pressure, . . 116.
Revolutions Per Minute, 112.
Revolutions Lever Notch, 9.
Throttle Notch, . . 6.
Spring, ... 60.

No. 4.



3½x2¾-Inch.



Boiler Pressure, . . 125.
Revolutions Per Minute, 120.
Revolutions Lever Notch, 9.
Throttle Notch, . . 6.
Spring, ... 60.

nozzle to each other. The manufacturers of locomotives made nozzles on the same general plan, but the size of the stack varied in a given engine from 14 to 18 inches, the rule in most general

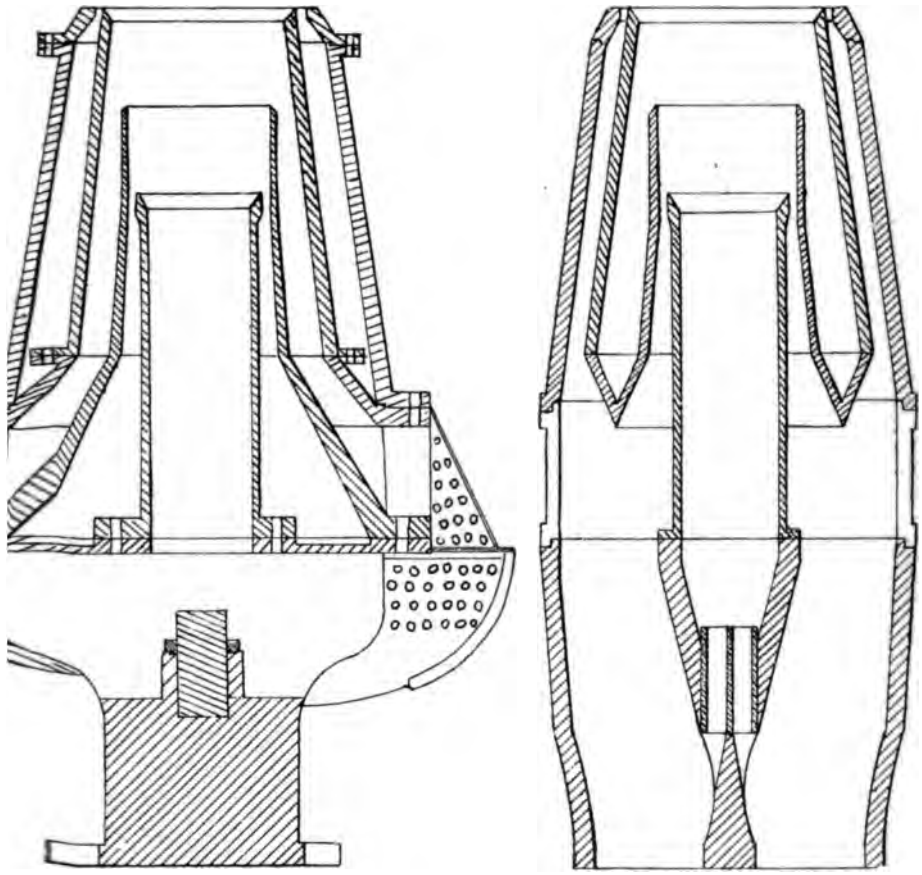


FIG. 5.

use being to make the stack of the same diameter as the cylinder. Recently, however, a stack contracted at the throat has been used quite satisfactorily on several railroads, and the Richmond and Danville took up the question of whether the double nozzle in these engines were giving satisfactory results. They went far enough to

[illegible]

[illegible] ... other results. ... that a few ... I ... and using a ... results. ... was again taken ... question but also ... existed between ...

[illegible]	[illegible]	[illegible]	Initial Pressure	Mean Effective Pressure	Mean Back Pressure and Compression	Indicated H.P. Both Cylinders	H.P. Lost by Back Pressure and Compression	Sum of I.H.P. and H.P. Lost by Back Pressure and Compression	Per Cent H.P. Lost by Back Pressure and Compression	Vacuum in Smoke Box in Inches of Water	Remarks
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Throttle notch 6.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.5	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	Reverse lever notch 9.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.53	5	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10.54	3	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.53	...	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.71	4	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	633.47	10.36	4.1	

Before going into the details of these experiments it is advisable to follow exactly the same course pursued prior to making them and determine the theoretical considerations to be met. The most careful and systematic analysis of the subject has been made in German locomotive practice. The French and English follow this

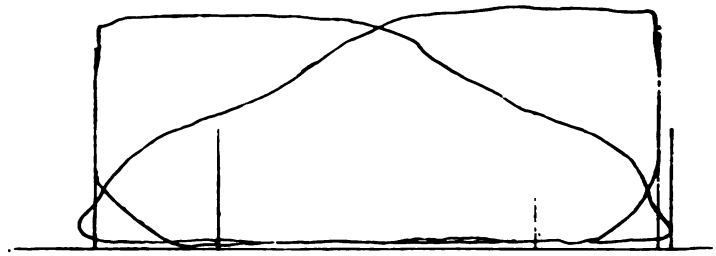
to a certain extent, while American practice of to-day is purely empirical.

Comparison of Results.	Best.				Worst.			
	Smith	3"x3"	3½"x3½"	3½"x3½"	Smith	3"x3"	3½"x3½"	3½"x3½"
Style of nozzle								
Revolutions per minute	66	74	59	64	106	106	124	110
Boiler pressure pounds per square inch	133	138	138	137	132	141	132	138
Initial pressure	119.5	132.5	135.5	138.5	124.5	129.5	107 5	123
Mean effective pressure	90.79	100.33	103.58	104.94	81.11	87.6	71.47	86.39
Mean back pressure and compression	5.62	5.11	3.075	4.77	13.65	9.5	7.38	8.48
Indicated horse-power	450.32	558.04	459.34	504.72	646.14	697.86	666.12	714.06
Horse-power lost by back pressure and compression	27.89	28.45	13.59	22.97	108.78	75.76	73.46	70.14
Sum of indicated horse-power and horse power lost by back pressure and compression	478.21	586.49	472.93	527.69	754.92	773.62	739.58	784.20
Per cent. horse-power lost by back pressure and compression	5.83	4.85	2.87	4.35	14.41	9.79	9.93	8.94
Vacuum in smoke-box in inches of water		4	2.5	3	5	5	3	4
Remarks.	Reverse lever—notch 9. Throttle lever—notch 6.							

For reference to German investigations see VOLUME III., "EISENBAHN TECHNIK," by Heusinger von Waldegg.

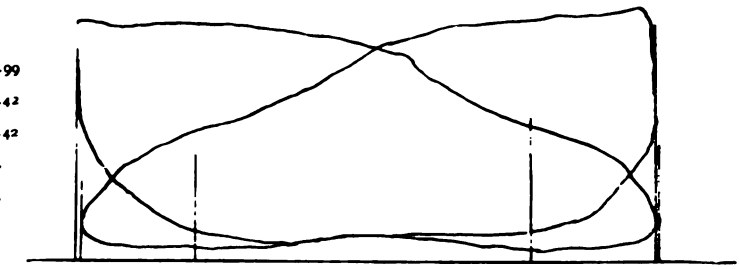
FIG. 6.—SMITH.

Length, . . . 2.94
Area, ... 2.66
B'k Press. Area, .17
Initial Press., 120.
Max. B'k Press., 5.



BEST.

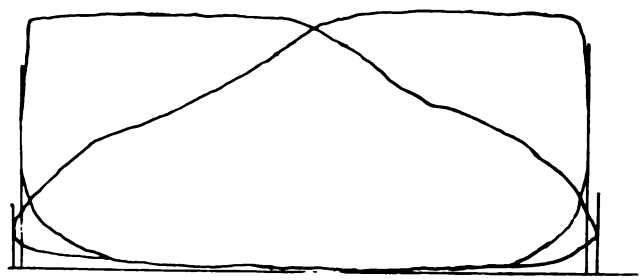
Length, . . . 2.99
Area, ... 2.42
B'k Press. Area, .42
Initial Press., 120.
Max. B'k Press., 10.



WORST.

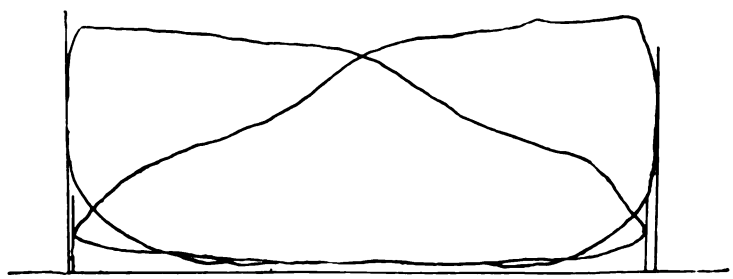
FIG. 7.
3x3 Inch

Length, ... 2.54
Area, ... 2.97
B'k Press. Area, .15
Initial Press., . 131.
Max. B'k Press., 2.



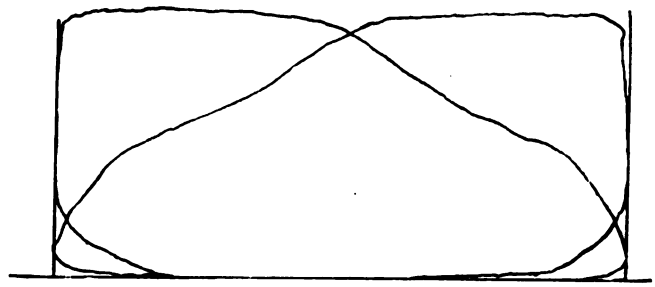
BEST.

Length, ... 2.94
Area, ... 2.58
B'k Press. Area, .29
Initial Press., 127.
Max. B'k Press., 7.



WORST.

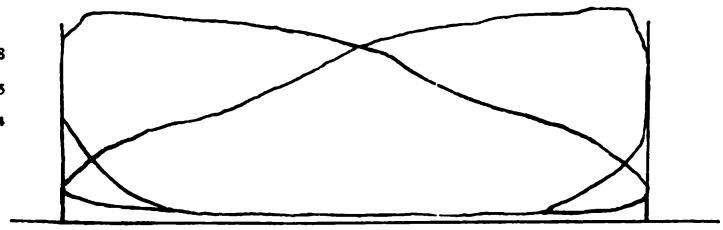
FIG. 8.
3¼x4¼-Inch.



. . 2.93
. . 3.05
. Area, .09
ess., 136.
Press., .50

Length, . . 2.92
Area, . . . 3.01
B'k Press. Area, .09
Initial Press., 135.
Max. B'k Press., .50

BEST.

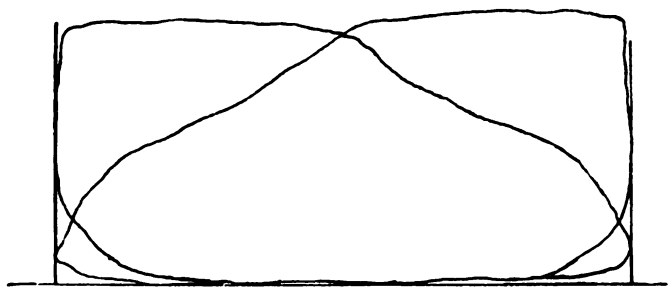


. . 2.98
. . 2.15
. Area, .24
ess., 106.
Press., 5.

Length, . . 2 98
Area, . . . 2.11
B'k Press. Area, .23
Initial Press., 108.
Max. B'k Press., 5.

WORST.

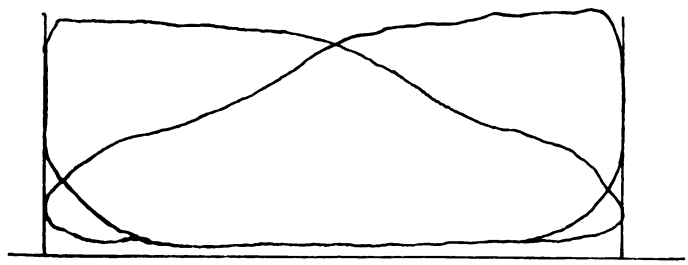
FIG. 9.
3½x3¼-Inch.



. . 2 93
. . 3.05
s. Area, .15
ress., . 136.
Press., 1.5

Length, . . . 2.93
Area, ... 3.10
B'k Press. Area, . .13
Initial Press., 141.
Max. B'k Press., . 1.5

BEST.



. . 2.94
. . 2.51
a. Area, .26
ress.,
Press., 6.

Length, . . 2.94
Area, . . . 2.57
B'k Press Area, .24
Initial Press., 126.
Max. B'k Press., 6.

WORST.

For the calculations of the dimensions we will consider the conical stack, since the cylindrical one is but a special case of the former. In Figs. 10 and 11, let:

U_p = the average velocity of steam issuing from the nozzle.

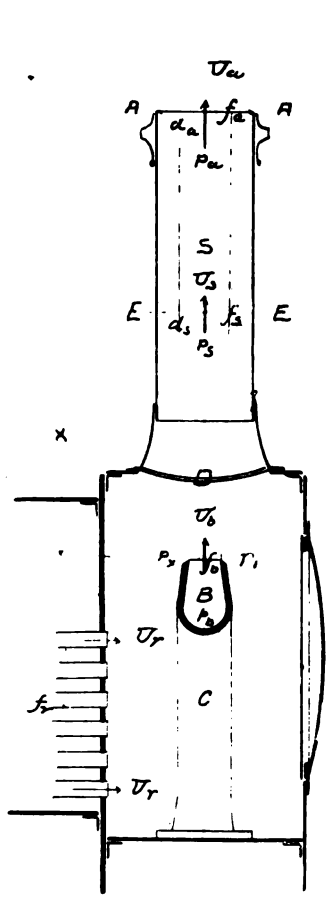


FIG. 10.

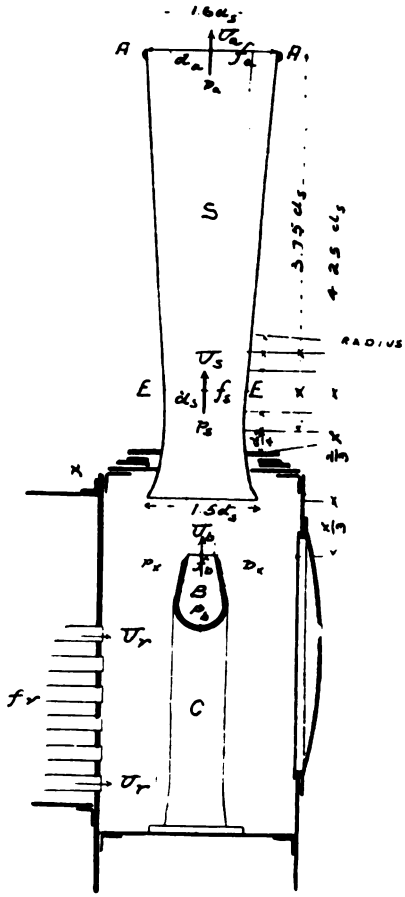


FIG. 11.

U_r = the velocity of the gases in the flues.

U_s = the average velocity of the gases and steam in the stack.

U_n = the velocity of exit of the steam and gases from the stack.

p_b = the sum of the pressure height and velocity height of the pipe c, corresponding to the blast pressure.

p_x = pressure in the smoke-box.

p_s = the pressure in the stack at $E\ E$.

p_a = pressure of atmosphere.

u = co-efficient of discharge of the nozzle opening.

f_b = area of nozzle.

f_s = minimum area of stack at $A\ A$.

f_r = total area of tubes or flues.

D = weight of steam per second issuing from the nozzle.

Q = weight of gases discharged per second.

y = weight of a cubic unit of the mixture of steam and gases taken separately because at the existing temperature and pressure they may be considered as equal.

$\frac{p_b}{y}, \frac{p_x}{y}$ and $\frac{p_s}{y}$ = heights (of Hg or H_2O) due to the pressure p_b, p_x and p_s.

The gases move horizontally into the smoke-box with a velocity U_r, which they lose partly on account of the area of the box and the change of direction to the stack. On account of the insignificance of the remaining velocity, for simplicity consider the gases as quiet before contact with the blast. The velocity of the steam relatively to the gases is at first U_b, which it gradually loses until both fluids attain a velocity U_s. On account of this relative motion, according to Carnot's laws, there exists a loss of energy due to impact or friction in the moving fluids.

If from the energy of the steam as it leaves the exhaust nozzle, there be subtracted every loss, remembering further that the particles in the smoke-box under a pressure p_x are subjected to a a greater pressure p_s in the stack, and must therefore be lifted by their energy through a height $\frac{p_s - p_x}{y}$, neglecting gravity, the equation for the remaining available energy in the steam at $E\ E$ is as follows:

$$(D+Q)\frac{U_s^2}{2g} = D\frac{U_b^2}{2g} - D\left(\frac{U_b - U_s}{2g}\right)^2 - \frac{Q\ U^2}{2g} - (D+Q)\frac{P_s - P_x}{y}$$

solving and reducing

$$\frac{D+Q}{D}\left(\frac{U_s^2}{g}+\frac{p_s-p_x}{y}\right)=\frac{U_b-U_s}{g}$$

But $D+Q=y\,.\,f_s\,.\,U_s$, and $D=y\,.\,u\,.\,f_b\,.\,U_b$, which substituted above gives:

$$\frac{f_s\,.\,U_s}{u\,f_b\,.\,U_b}\left(\frac{U_s^2}{g}+\frac{p_s-p_x}{y}\right)=\frac{U_b-U_s}{g}$$

and therefore the difference in the pressure heights at $E\,E$ in the stack and smoke-box

$$\frac{p_s-p_x}{y}=\frac{u\,f_b}{f_s}\,.\,\frac{U_b^2}{g}-\frac{U_s^2}{g}\qquad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.)$$

For the motion of the column of gas and steam above $E\,E$ neglecting friction in the stack

$$\frac{U_s^2}{2\,g}+\frac{p_s}{y}=\frac{U_a^2}{2\,g}+\frac{p_a}{y}$$

from which the pressure height at $E\,E$ may be found:

$$\frac{p_s}{y}=\frac{p_a}{y}-\frac{U_s^2}{2\,g}-\frac{U_a^2}{2\,g}$$

Since $f_a\,.\,U_a=f_s\,.\,U_s$, the above becomes

$$\frac{p_s}{y}=\frac{p_a}{y}-\frac{U_s^2}{2g}\left[1-\left(\frac{f_s}{f_a}\right)^2\right]\qquad\ldots\ldots\ldots\ldots\ldots(2.)$$

The substitution of this value in 1, gives the difference in pressure height of the atmosphere and smoke-box

$$\frac{p_a-p_x}{y}=\frac{u\,f_b}{f_s}\,.\,\frac{U_b^2}{g}-c\,.\,\frac{U_s^2}{g}\qquad\ldots\ldots\ldots\ldots\ldots\ldots(3.)$$

which from the conical shape of the stack reduces to the fraction

$$\frac{1+\left(\frac{f_s}{f_a}\right)^2}{2}=c\qquad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.)$$

This equation holds good for cylindrical stacks when $f_a=f_s$ or $c=1$.

Since the steam and gases pass through the stack at the same time it follows that

$$y\,.\,f_s\,.\,U_s=y\,.\,u\,f_b\,.\,U_b+y\,.\,f_r\,.\,U_r\,.\text{ whence}$$

$$U_s=\frac{u\,f_b}{f_s}\,.\,U_b+\frac{f_r}{f_s}\,.\,U_r\,.$$

which substituted in 3 gives

$$\frac{p_a - p_x}{y} = \frac{u f_b}{f_s}\left(1 - c\frac{u f_b}{f_s}\right)\frac{U_b^2}{g} -$$

$$2c\frac{u f_b}{f_s}\cdot\frac{f_r}{f_s}\times\frac{U_b U_r}{g} - c\left(\frac{f_r}{f_s}\right)^2\cdot\frac{U_r^2}{g} \quad \ldots\ldots\ldots\ldots (5.)$$

The determination of the velocities of exit, U_b and U_r may be obtained from the simple equations,

$$U_b = \sqrt{2g\frac{p_b - p_x}{y}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6\ a.)$$

$$U_r = \psi\sqrt{2g\frac{p_a - p_x}{y}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6\ b.)$$

since the difference of pressure p_b, p_x, p_a is very small, ψ in the equation (6 *b*) is a reduction co-efficient which takes into account the resistance of the air through the flues and is dependent on the position of the ash-pan damper, size of spaces between grate bars, condition of fire, cross-section and length of tubes, also on the resistance of the screen in the smoke-box. For an average proportion the value of ψ is between .3 and .4.

It can, however, be made less by the shutting of the ash-pan damper, while a wide opening of the same, a larger free grate area, lower and looser fire bed, wider and shorter tubes, all tend to raise its value.

Substituting in (5) the values found in (6), we have,

$$A(p_b - p_x) - B(p_a - p_x) = \sqrt{(p_b - p_x)(p_a - p_x)} \quad \ldots\ldots (7.)$$

$$A = \frac{1 - c\frac{u f_b}{f_s}}{2\Psi c\frac{f_r}{f_s}}; \quad B = \frac{1 + 2\Psi^2 c\left(\frac{f_r}{f_s}\right)^2}{4\Psi c\frac{u f_b}{f_s}\cdot\frac{f_r}{f_s}} \quad \ldots\ldots\ldots\ldots (7\ a.)$$

In a particular engine A and B are constants if f_b and Ψ, and therefore the position of the nozzle, ash-pan damper and height of fire-bed remain unchanged.

Squaring (7) and collecting,

$$(p_b - p_x)^2 - \frac{2AB + 1}{A^2}(p_a - p_x)(p_b - p_x) + \frac{B^2}{A^2}(p_a - p_x)^2 = 0.$$

The solution of this equation determines the blast pressure which is necessary for the maintenance of a certain vacuum in the smoke-box, therefore,

$$p_b - p_x = (p_a - p_x)\frac{2AB+1}{2A^2}\left[1 \pm \sqrt{1-\left(\frac{2AB}{2AB+1}\right)^2}\right]$$

From the two valves $p_b - p_x$, which accordingly correspond to the desired $p_a - p_x$, the smaller may be found by means of the back pressure on the piston.

The numerical calculation shows directly that $2AB$ is large compared to unity and that $\frac{2AB}{2AB+1}$ is not essentially different from unity so that the quantity under the radical may be neglected —therefore

$$\frac{p_b - p_x}{p_a - p_x} = \frac{2AB+1}{2A^2} \quad \ldots\ldots\ldots\ldots\ldots (8.)$$

Subtracting one from each side of the equation, (8) becomes

$$\frac{p_b - p_a}{p_a - p_x} = \frac{2AB+1}{2A^2} - 1 \quad \ldots\ldots\ldots\ldots (8a.)$$

Under certain suppositions if A and B are constant then $\frac{2AB+1}{2A^2}$ and $\frac{2AB+1}{2A^2} - 1$ are constant. Accordingly (8 a) contains the ratio of the pressure of the blast to the vacuum in the smoke-box. To determine this ratio substitute in (8) the values of A and B from (7 a) which gives

$$\frac{p_b - p_x}{p_a - p_x} = \frac{f_s}{uf_b} \cdot \frac{1 + 2c\Psi^2\left(\frac{f_r}{f_s}\right)^2 \frac{\frac{f_s}{uf_b} + c}{\frac{f_s}{uf_b} - c}}{2\left(1 - c\cdot\frac{uf_b}{f_s}\right)} \quad \ldots\ldots\ldots (9.)$$

from which it follows that $\frac{p_b - p_a}{p_a - p_x} = \frac{p_b - p_x}{p_a - p_x} - 1 \ldots\ldots\ldots (9a.)$

For $c = 1$ and the average proportions $\frac{f_s}{uf_b} = 13$; $\frac{f_r}{f_s} = 2$; $\Psi = \frac{1}{3}$; $\frac{p_b - p_x}{p_a - p_x} = 14.36$ and $\frac{p_b - p_a}{p_a - p_x} = 13.36$; that is to say, that

under these assumptions, the vacuum in the smoke-box is the $\frac{1}{13.36}$ of the pressure of the blast, and if measured by means of columns of water and mercury respectively, the heights of both will be equal. By means of equation (9) may be determined the weight of gas taken out of the smoke-box by the exhaust steam. By the division of the equations

$$Q = y \,.\, f_r \,.\, U_r$$
$$D = y \,.\, uf_b \,.\, U_b$$

and by means of (6 *a*) and (6 *b*) it follows that

$$\frac{Q}{D} = \Psi \frac{f_r}{uf_b} \sqrt{\frac{p_a - p_x}{p_b - p_x}} \,.$$

Substituting from (9) the value for $\frac{p_a - p_x}{p_b - p_x}$ gives

$$\frac{Q}{D} = \frac{\sqrt{\frac{f_s}{uf_b} - c}}{\sqrt{\frac{1}{2\Psi^2}\left(\frac{f_s}{f_r}\right)^2 + c}\,\frac{\frac{f_s}{uf_b} + c}{\frac{f_s}{uf_b} - c}} \quad \ldots\ldots\ldots (10.)$$

Allowing that f_s is very large compared to uf_b it follows that $\frac{\frac{f_s}{uf_b} + c}{\frac{f_s}{uf_b} + c}$ is nearly unity, which substituted in (10) gives the somewhat simpler form

$$\frac{Q}{D} = \sqrt{\frac{\frac{f_s}{uf_b} - c}{\frac{1}{2\Psi^2}\left(\frac{f_s}{f_r}\right)^2 + c}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10a).$$

The discussion of equation (10) shows that the ratio of the weight of gas to the weight of steam necessary, for constant values of f_b, f_r, f_s, Ψ, and c, is constant and independent of the ruling pressure of the blast. In the case of slow travel of the engine, with strong intermittent blast, a periodical tearing of the fire takes place, which is not favorable to good combustion, while for faster speeds the

comparative evenness of the blast produces a more even draught. Now, whether the ratio of weight of air to weight of steam is sufficient for the required draught depends on the magnitude of the values in question. A kilogramme of coke gives 14.5 kilogrammes of gases, and, under ordinary circumstances, 6.25 kilogrammes of steam; so that one kilogramme of steam carries off 2.3 kilogrammes of the gases or $\frac{Q}{D} = 2.3$. For coal the respective values are 16 and 5.75; $\therefore \frac{Q}{D} = 2.8$.

In relation to the cross-section of the stack, it is seen from (10) and (10 *a*) that for a particular engine a certain area, f_s, must be given which makes $\frac{Q}{D}$ a maximum, or affords the strongest draught, and further is the most advantageous for the lowering of the blast pressure.

For $f_s = c \,.\, u f_b$ and $f_s = \infty$, $\frac{Q}{D}$ becomes 0, and intermediate values make $\frac{Q}{D}$ finite and positive. The smaller values for f_s are not considered, since naturally f_s must be greater than $u f_b$. For the most advantageous cross-section of the stack, consider f_s as variable in (10) and solve for a maximum.

$$\left(\frac{f_s}{f_r}\right)^3 - 3c\,\frac{u f_b}{f_r}\left(\frac{f_s}{f_r}\right)^2 - 2c\left[\psi^2 - c\left(\frac{u f_b}{f_r}\right)^2\right]\left(\frac{f_s}{f_r}\right) - 6c^2\,\psi^2\,\frac{u f_b}{f_r} = 0.$$

The numerical solution of the above equation is not difficult, but inconvenient, to handle. In order to ascertain whether the importance of the case makes necessary this trouble, since only ratios of areas are concerned, substitute in (10) and (10 *a*) two consecutive values for $\frac{f_s}{f_r}$ and take the ratio corresponding to practice $\frac{f_r}{u f_b} = 24$;

$\Psi = \frac{1}{3}$; $c = 1$. The results of the calculation are given in the following table:

For $\frac{f_s}{f_r}$ = ...	$\frac{8}{24}$	$\frac{9}{24}$	$\frac{10}{24}$	$\frac{11}{24}$	$\frac{12}{24}$	$\frac{13}{24}$	$\frac{14}{24}$	$\frac{15}{24}$	$\frac{16}{24}$	$\frac{17}{24}$	$\frac{18}{24}$
(10). $\frac{Q}{D}$ = ...	1.98	2.06	2.12	2.16	2.18	2.20	2.20	2.20	2.19	2.17	2.16
(10 *a*). $\frac{Q}{D}$ = ...	2.16	2.21	2.25	2.27	2.276	2.274	2.27	2.25	2.23	2.22	2.19

The above cubical equation gives $\frac{f_s}{f_r} = 0.58$, or $\frac{13.92}{24}$ in accordance with the results obtained from (10), while formula (10 *a*) gives for the most advantageous cross-section a little smaller value, $\frac{2.12}{24} f_r$, and even indicates that the admission of air is better. But it is seen from the table that the area of the stack may be varied considerably from the most advantageous values without suffering material loss in its efficiency.

Still further remember that the filling of the stack with gases and steam at each $\frac{Q}{D}$ is absolutely necessary to prevent the entrance of air between the jet and sides of the stack, and it is better to use an area narrower than the most advantageous area instead of a larger one.

Differentiating (10*a*) and placing the first derivative = 0 gives

$$\left(\frac{f_s}{f_r}\right)^2 - 2c\frac{uf_b}{f_r}\left(\frac{f_s}{f_r}\right) - 2c\psi^2 = 0$$

from which

$$\frac{f_s}{f_r} = c\frac{uf_b}{f_r} \pm \sqrt{\left(c\frac{uf_b}{f_r}\right)^2 + 2c\psi^2}.$$

neglecting the value of

$$\left(c\frac{uf_b}{f_r}\right)^2$$

as small compared with $2\,\psi^2\,c$, the above becomes near enough

$$\frac{f_s}{f_r} = c\,\frac{u f_b}{f_r} + \psi\sqrt{2\,c} \qquad (11.)$$

Equation (11) shows distinctly that the most advantageous cross-section of the stack f_s is dependent on the values of c, ψ . f_r and f_b; it is but little influenced by small changes in the cross-section of the nozzle and receives its value from the cross-section (area) of the flues, f_r, and the co-efficient Ψ. The investigations of Hovo and Geoffroy with cylindrical stacks confirm this. Therefore for cylindrical stacks the ratio $\frac{f_s}{f_r} = 0.5$ ..... (11 *a*.)

Before equation (11) can be utilized for conical stacks the influence of c on $\frac{Q}{D}$ must be determined. Equations (10) and (10 *a*) show that for a decrease of c which corresponds to an increase of f_a, $\frac{Q}{D}$ decreases. The smallest value c is when $f_a = \infty$,

$$\frac{1 + \left(\frac{f_s}{\infty}\right)^2}{2} = 0.5.$$

The following table shows, for different values of c, its influence on $\frac{Q}{D}$

For c = ...	1	0.9	0.8	0.7	0.6	0.55	0.50
$\frac{f_s}{f_r}$ —	0.46	0.43	0.40	0.38	0.35	0.33	0.32
$\frac{Q}{D}$ —	2.35	2.42	2.50	2.60	2.71	2.78	2.85

The values for $\frac{f_s}{f_r}$ are found from (11) making $\frac{u f_b}{f_r} = \frac{1}{36}$, $\psi =$ 3. For values of $\frac{Q}{D}$ use equation (10). The greatest quantity of

air that can pass through a conical stack with $c = 0.5$, according to the table, is equal to 1.21 times the quantity traversing a cylindrical one having the same values for f_b and ψ. Hence, for a given amount of draught the nozzle becomes larger in a conical than in a cylindrical stack, thereby diminishing the blast pressure and consequently the back pressure. This circumstance makes the conical stack the more preferable. In Prüsmann's stacks $c = .55$, $\frac{Q}{D} = 278$, or 1.18 times as much air as afforded by a cylindrical one if they have the same ratio $\frac{f_s}{f_r} = \frac{1}{3}$... .....(11 *b*.)

They are too narrow, however, (due to the error in supposing that the passage of steam through thin sheets of metal, is the same as its motion in pipes) and give for $\frac{f_s}{f_r} = \frac{1}{4}$ in 10, $\frac{Q}{D} = 2.65$, or 1.12 times the quantity of air that a cylindrical one does. If for a conical stack the more suitable value $\frac{f_s}{f_r} = \frac{1}{3}$ be taken and the diameter at the top = 1.6 times the smallest diameter, or

$$\left(\frac{f_s}{f_r}\right)^2 = 0.153,\ c = 0.58,$$

then $\frac{Q}{D} = 2.74$. A stack so designed will give $\frac{2.74}{2.34} = 1.16$ times as much air as a cylindrical one and 4 per cent. more than the Prüsmann.

Having a value for $\frac{f_s}{f_r}$ it is possible with equation (10) to determine the most effective area, f_b, of the nozzle, to produce, (assuming Ψ) a particular value of $\frac{Q}{D}$.

The solution of this equation for $\frac{f_s}{u f_b}$ gives

$$\frac{f_s}{u f_b} = \left\{ \left[1 + \tfrac{1}{2}\left(\frac{Q}{D}\right)^2 \right] c + \tfrac{1}{2}\left(\frac{Q}{D}\right)^2 \frac{1}{2\Psi^2} \left(\frac{f_s}{f_r}\right)^2 \right\} \times$$

$$\left[1 \pm \sqrt{1 + c\,\frac{\left[\left(\frac{Q}{D}\right)^2 - 1\right]c - \left(\frac{Q}{D}\right)^2 \frac{1}{2\Psi^2}\left(\frac{f_s}{f_r}\right)^2}{\left\{\left[1 + \tfrac{1}{2}\left(\frac{Q}{D}\right)^2 c + \tfrac{1}{2}\left(\frac{Q}{D}\right)^2 \frac{1}{2\Psi^2}\left(\frac{f_s}{f_r}\right)^2\right\}^2}}\right]$$

The quantity under the square root sign is so small that it may be neglected. The above equation then reduces to the somewhat simple form

$$\frac{f_s}{u f_b} = \left[2 + \left(\frac{Q}{D}\right)^2\right] c + \left(\frac{Q}{D}\right)^2 \frac{1}{2\Psi^2}\left(\frac{f_s}{f_r}\right)^2 \ldots\ldots\ldots (12)$$

If the average values $\Psi = \frac{1}{3}$, $u = 0.9$, $\frac{Q}{D} = 2.8$ be substituted in (12), for the calculation of a constant blast opening

$$\frac{f_s}{f_b} = 8.8c + 31.7\left(\frac{f_s}{f_r}\right)^2 \ldots\ldots\ldots\ldots (12a.)$$

Assuming the most advantageous values for $\frac{f_s}{f_r}$, (11 *a*) and (11 *b*) give after a slight rounding off, the value $\frac{f_s}{f_b} = 11.9$ for cylindrical and 6.2 for conical stacks.

If on account of the variation of f_s, f_r be introduced into the equation, after a further rounding off due to the variation of Ψ, for cylindrical stack $\frac{f_r}{f_b} = 33$, for conical stack $\frac{f_r}{f_b} = 26$. For a variable nozzle the largest opening is not made much different from the area of the exhaust pipe, while the smallest opening must be so measured that for the strongest firing, with smallest value of Ψ and greatest $\frac{Q}{D}$, it will furnish a strong enough draught.

Of the greatest importance is the distance of the tip of the nozzle from the throat of the stack, since on this is dependent for best effect the necessary surface of contact between the steam and gases. If more were known of the form of the column of exhaust steam it would be very easy to determine the distance from the

nozzle to the stack to produce the best effect through an area $E\,E$. The determination, however, may be made by an approximation.

Through this area there passes $Q + D$ cubic feet of gases and steam at a velocity U_s.

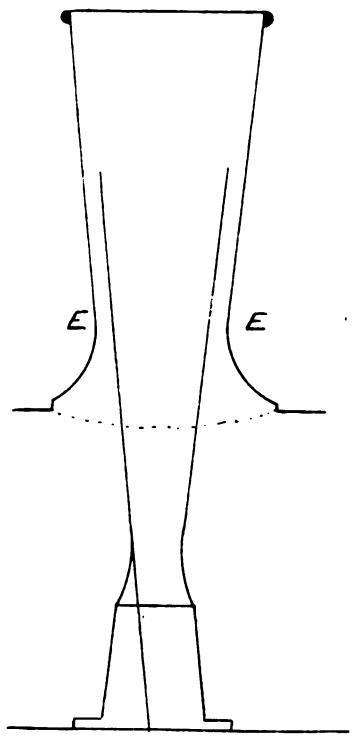


FIG. 12.

Let d_s be the diameter of the stack at $E\,E$, then

$$\frac{\pi\, d_s^2}{4} = f_s = \frac{Q + D}{y \,.\, U_s}$$

from which the area of the column of the steam equals

$$\frac{D}{Q + D} \cdot f_s,$$

hence, with a circular nozzle the diameter of the column must be

$$d_s \sqrt{\frac{D}{Q + D}}.$$

Assuming that the form of the exhaust jet is conical, imagine a second cone drawn from $E\,E$ as a base and coinciding almost with the first; the diameter at the nozzle of the second cone is that of the nozzle d_b, while that of the cone of steam at the same place is somewhat less, due to the contraction of the jet. Calling this diameter $a \cdot d_b$, the angle of the cones to the vertical axis $= \beta$, then for any distance, x, the diameter at that point $= a\,d_b + 2\,x \tan \beta$; but this diameter must also equal the one above, therefore

$$a\,d_b + 2\,x \tan \beta = d_s \sqrt{\frac{D}{Q + D}}$$

from which

$$x = \frac{d_s}{2 \tan \beta} \sqrt{\frac{D}{Q + D}} - \frac{a}{2 \tan \beta} \cdot d_b. \quad \ldots\ldots (13.)$$

From Prüsmann's investigations

$$x = 5\,(d_s - 2\,d_b).$$

In the cylindrical stack $d_b = \frac{1}{4}\,d_s$ (about) $\therefore x = 2.5\,d_s$. To insure a good vacuum in the smoke-box at low speed, the height of the stack above the smallest diameter $= 4\,d_s$. On account of the uncertainty of the determination of the distance x, it is recommended to maintain a cylindrical form in the stack for a distance equal to $\frac{1}{2}\,d_s$ above and below $E\,E$. The upper part is made conical and a complete filling of the area by gases and steam may be obtained if the sides be given an inclination of 1 in 12½ to the axis. This obliquity is obtained if the height of the conical part is made $= 3.75\,d_s$ and the upper diameter $1.6\,d_s$.

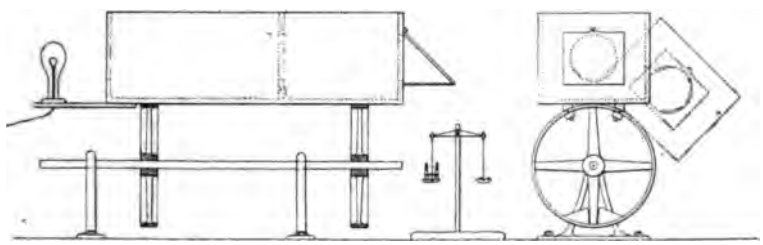
To insure the entrance of the steam into the stack, a conical piece with 1 in 7 inclination is fastened to the lower end of the stack extending down a distance equal two-thirds the distance from the throat of the stack to the nozzle tip, the lower diameter being $1.5\,d_s$.

(TO BE CONTINUED.)

ON THE CANDLE-POWER OF CANDLES, AT AN ANGLE OF 45 DEGREES WITH THE HORIZONTAL.

BY PROF. WM. E. GEYER.

IN the course of the summer I had occasion to measure the amount of light emitted by certain railroad lamps at an angle of 45 degrees downward from the horizontal line. The photometer box was tilted to this angle and the light tested against standard candles. As the candles must necessarily stand vertical, the question arose whether the light a candle emits in a direction 45 degrees upwards is of the same intensity as that emitted horizontally. To test the question, the simple arrangement shown in the accompanying figure was gotten up from materials at hand. A short photometer box provided with carriage for the greased paper disc, and with partitions to avoid internal reflection, was mounted on the rims of two pulleys. These pulleys were fixed to a short piece of shaft-



ing and this again was carried in proper bearings. Counterweights were tied to the pulleys at the side diametrically opposite the photometer. In this way the photometer box, with all its attachments, could be instantly moved between proper stops, from a position in which a flame through its axis and through the shaft was horizontal to one in which this flame made an angle of 45 degrees with the former position. The candles were placed in the prolongation of the shaft and their light reflected into the photometer by a silver mirror attached to one end of the box, and, of course, turning with

the box when the pulleys were revolved. The candles were tested against a miniature incandescent lamp mounted on the other end of the movable photometer. The current was adjusted until the color of the light was of the same shade as that of the candles, and the distance of the lamp was fixed so that balance on the disc was obtained at about the middle of the box. It will be seen that by these arrangements all corrections are eliminated. The incandescent lamp swings with the photometer and must throw the same amount of light into it at all angles. The candles are left undisturbed, while their light at any desired angle above the horizontal line can be thrown into the photometer, the angle of reflection at the mirror being, however, always the same, and thus eliminating corrections for losses at the mirror. The reading in the horizontal and in the 45 degree positions can be made in rapid alternations, so that candle rate need not be noted.

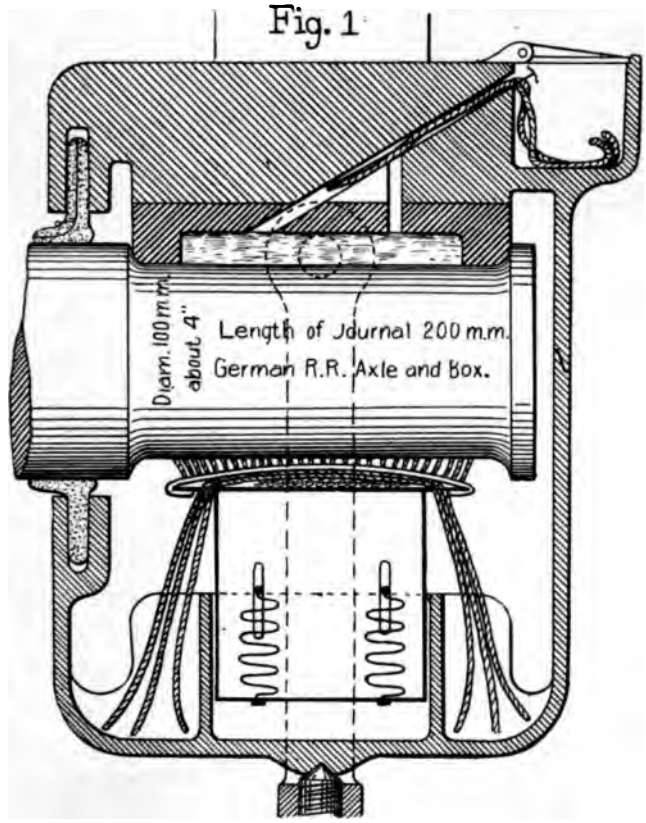
Supposing the candle flame to be somewhat opaque to its own light, I was prepared to find a very slight diminution of the light in the 45 degree position. Such was not the case. When the photometer was rapidly moved from one position into the other, in general no change could be detected on the disc, or if at times a change seemed noticeable, it was in the direction to indicate that in the 45 degree position the light was a little stronger. The result of numerous settings goes to show that if this difference does exist it is not greater than a quarter of 1 per cent. If we still assume that in the 45 degree position the flame cuts off somewhat more of its own light the result may be explained by considering that the concave cup of the candle acts as a reflector. As it can hardly be claimed that photometer observations are exact to a quarter of 1 per cent., it will be safe for all practical purposes to consider the light of standard candles the same, whether looked at in a horizontal direction or along a line inclining 45 degrees downwards.

METHOD OF LUBRICATING CAR AXLES ON GERMAN RAILWAYS.

BY PROF. J. E. DENTON.

AT the request of the writer, Mr. F. T. Gause, '91, (during his location for some weeks in Hamburg, in connection with lubricating oil experiments for the Standard Oil Company), made the following notes regarding the most improved methods of lubricating car axles on German railways.

Fig. 1



The fresh lubricating oil is fed to a reservoir at the top of the box, Fig. 1, and reaches the journal by wick syphon. A pad of elaborate construction, Fig. 2, is pressed against the lower surface of the journal, and is kept saturated by capillary, or syphon action, from oil carried in the bottom of the box, Figs. 1 and 4. A felt ring, Fig. 3, fits snugly in an annular groove in the box, and is made to hug the axle closely by means of two light brass spiral springs. This prevents the escape of oil from and the entrance of dust to the box.

The speed of trains ranges from 56 English miles per hour for passenger service to 28 miles for freight service. The number of axles per passenger car varies from two to four.

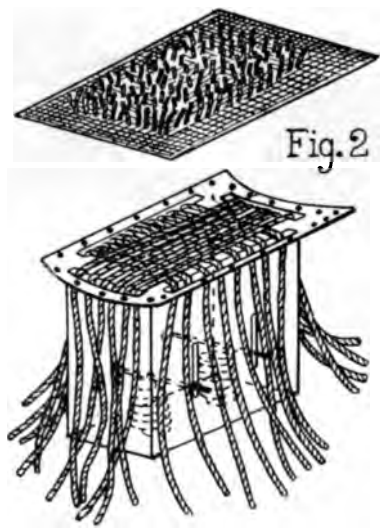


Fig. 2

Passenger trains of six cars, running 176 miles between Hamburg and Berlin, averaging a total of 15 axles, use one-fourth of a pint of oil per axle per 100 miles. The pressure per square inch of projected area of bearings averages about 325 pounds, and the rubbing velocity about 400 feet per minute. The pressure per square inch, rubbing speed, and the quality of lubricating oil, are practically the same as are common to American passenger traffic,

in which the oil is applied by saturating a loose mass of woolen or cotton waste, and a dust guard is used consisting of a disc of leather or wood. The average consumption of oil in American practice is given by Hall's "Car Lubrication" as two-fifths of a pint per axle per 100 miles. The writer has noted, however, that first-class American passenger service consumes one pint per axle per 100 miles.

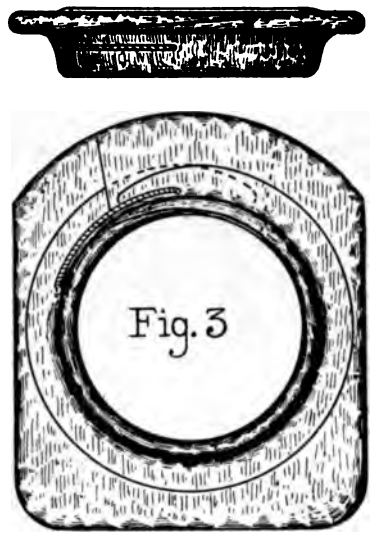


Fig. 3

A much lower rate of oil consumption has been reported for the European "pad feed" box, than is given by Mr. Gause. For example, Wellington, in his "Economic Theory of Railway Location," quotes a consumption of one-seventieth of a pint per axle per 100 miles. Such results do not, however, represent the *average* consumption, but rather possibilities, when special care is used to limit the consumption by following a car for a test with bearings in the best condition. Under such conditions the use of woolen waste has permitted the consumption to be as low as one-tenth of a pint per axle per 100 miles. There is no doubt that the use of a

"pad" instead of waste, and of a more elaborate dust guard, may reduce the average consumption to one-fourth that common with

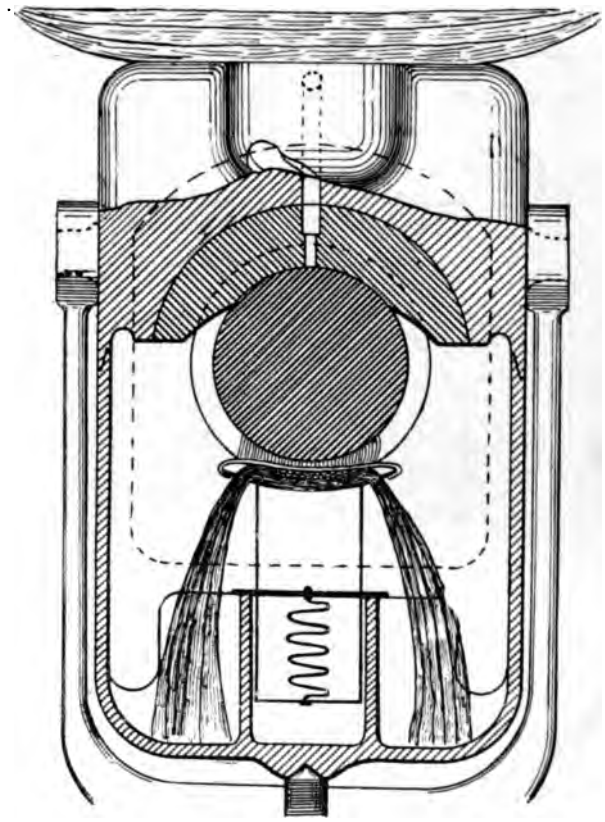


Fig. 4

waste, but the greater care necessary to maintain springs and syphons, in good working order, has thus far made the use of waste preferable in American practice.

CALCULATION OF THE HEAT OF COMBUSTION OF AN ILLUMINATING OIL GAS AND COMPARISON WITH THE HEAT DETERMINED BY EXPERIMENT.

BY PROF. D. S. JACOBUS.

THE composition of the gas considered, as determined by a number of analyses*, gave the following per cents by volume:

Carbonic acid	.5
Marsh gas	57.7
Hydrogen	3.4
Illuminants	38.1
Nitrogen	.3

The illuminants, or the hydrocarbon gases, with the exception of marsh gas, cannot be separated from each other without a very elaborate analysis, so that for the present purpose the subdivision of the 38.1 per cent. given above is assumed at two probable figures, one of which will tend to give a high heat of combustion per cubic foot of gas, and the other a low heat of combustion. The difference in the heat of combustion under the two assumptions amounts to 8 per cent. The experimental value for the gas in question falls between the two theoretical values. The two assumed divisions of the 38.1 per cent. by volume of the illuminants are as follows:

	1st Division.	2nd Division.
Benzole vapor C_6H_6	5.0	10.0
Propylene C_3H_6	10.0	10.0
Olefiant gas C_2H_4	23.1	18.1

The theoretical heat of combustion for the first division is 1,231 B. T. U. per cubic foot of gas at 85° F., which was the temperature of the gas in making the experimental determination of the heat of combustion. For the second division the theoretical heat of combustion is 1,337 B. T. U. The heat of combustion by direct experiment is 1,247 B. T. U. per cubic foot.

The method of making the heat measurements and a description, in detail, of the apparatus used will be presented at the

*Analyses made by Dr. William E. Geyer.

New York meeting of the American Society of Mechanical Engineers next November in connection with a paper on the Heat Generated per Candle-Power by Oil and Gas Lamps.

A general description of the apparatus was presented at the Rochester meeting of the American Association for the Advancement of Science, which is as follows:

"The lamps are placed in an air-tight box, leading to th bottom, and from the top of which are galvanized-iron pipes. Th top exit pipe is furnished with a damper and a special deflecto device to thoroughly mix the air before its temperature i measured. For still further accuracy in measuring the exit tem peratures five thermometers are used at the same cross-section o the pipe with their bulbs located at the center, edges, and at intermediate positions. Arrangements are made so that radiant heat either direct or reflected, cannot affect the readings of the thermometers. The lamps are run at the required candle-power, and the readings of the temperatures and of an anemometer placed in the inlet pipe carefully noted. After running steadily for about three hours the lamp is taken out and a steam radiator coil put in its place. By regulating the amount of steam that flows into the radiator the temperatures and reading of the anemometer are made the same as for the lamp. The amount of heat given up by the radiator coil is then the same as that given up by the lamp, and may be determined from the weight of steam condensed. To make certain of the quality of the steam entering the radiator it is slightly superheated and its pressure accurately measured. The temperature of the entering steam and of the condensed water leaving the coil is measured by means of thermometers placed in mercury wells. The coil is arranged so that the condensed steam drains readily from it. If any portion of the coil or pipes leading to and from it tends to hold back the condensed steam it will flow from the coil in an irregular way, and exact readings cannot be obtained. The condensed steam flows downward to a small stand-pipe containing a gauge glass in which it is held at a certain height by throttling a discharge valve It is finally discharged under the surface of cold water so that there is no loss from evaporation. The advantage of this method is that the effect of radiation from the box may be eliminated so that an accurate standardization of the anemometer is unnecessary."

As a general check on the accuracy of the measurements, the heat of combustion of petroleum illuminating oil as deduced theoretically was compared with that determined by experiment; this showed that the heat by experiment was about 1.1 per cent. lower than that deduced from the analysis. In similar comparisons, made by H. St. Claire de Ville on Russian petroleums, the difference was found to range from 1.7 per cent. to 3.5 per cent.*

The detailed calculations of the heat of combustion of the gas are given in Tables I. and II.

TABLE I.—*Calculation of the Total Heat per Pound of Gas. First Division of Illuminants.*

GAS.	Per Cents. by Volume.	Density.	Weight in Terms of an Equal Volume of Air.	Per Cents. by Weight.	Heat Units Per Pound.	Heat Units in Portions Contained in one Pound of Mixture.
Benzole vapor, C_6H_6....	5.0	2.770	.1385	16.4	17,702	2,903
Propylene, C_3H_6.....	10.0	1.451	.1451	17.2	19,737	3,395
Olefiant gas, C_2H_4.....	23.1	.978	.2259	26.8	20,050	5,373
Carbon monoxide, CO.	.5	.973	.0049	.6	4,369	26
Marsh gas, CH_4.....	57.7	.559	.3225	38.3	21,425	8,206
Hydrogen, H..... ...	3.4	.069	.0023	.3	52,368	157
Nitrogen, N.....	.3	.972	.0029	.3	0	0
		Density	=.8421	B. T. U.	per lb.=	20,060

B. T. U. per cubic foot at 85° F.= $\frac{20{,}060 \times .8421}{13.72}$ = 1,231.

In the calculations given in Tables I. and II. the heats of combustion, with the exception of that of hydrogen, have been reduced from the experimental values of Julius Thomsen,† in the translation of which I have been kindly assisted by Professor Riesenberger. The latent heat of the water vapor in the products of combustion has been deducted from the total amount in obtaining the figures

* *Comptes Rendus*, page 192, 1871.

† *Thermochemische Untersuchungen von Julius Thomsen.*

employed in the tables. The method of making the deduction and of reducing to British units is given in Table III.

In allowing for the water vapor the latent heat is taken at that corresponding to the temperature at which the vapor was condensed in Thomsen's experiments. This is 64.4° F., at which temperature the latent heat is 1,068 B. T. U. per pound. Column 6 in Table III. is therefore obtained by multiplying the quantities given in column 5 by 1,068.

TABLE II.—*Calculation of Total Heat per Pound of Gas. Second Division of Illuminants.*

GAS.	Per Cents. by Volume.	Density.	Weight in Terms of an Equal Volume of Air.	Per Cents. by Weight	Heat Units per Pound.	Heat Units in Portions Contained in one Pound of Mixture.
Benzole vapor, C_6H_6...	10.0	2.770	.2770	29.7	17,702	5,257
Propylene, C_3H_6.....	10.0	1.451	.1451	15.6	19,737	3,079
Olefiant gas, C_2H_4. ..	18.1	.978	.1770	19.0	20,050	3,809
Carbon monoxide, CO.	.5	.973	.0049	.5	4,369	22
Marsh gas, CH_4	57.7	.559	.3225	34.6	21,425	7,413
Hydrogen, N.....	3.4	.069	.0023	.2	52,368	105
Nitrogen, N.....	.3	.972	.0029	.3	0	0
		Density	=.9317			19,685

B. T. U. per cubic foot, at 85° F. $= \frac{19.685 \times .9317}{13.72} = 1,337.$

The heat of combustion of hydrogen is that deduced from the experiments of Favre and Silbermann, as published by them in 1852.* This was some time after their determination on the heat of combustion of hydrogen was first published, at which time they reported that the heat in calories per kilogram was 34,188.† The value reported in 1852 was 34,462 calories per kilogram, or 62,032 B. T U. per pound. The experiments were made at 54° F., so that the

* *Annales de Chimie et de Physique*, 1852.

† *nptes Rendus*, Vol. XVIII, 1844, p. 695.

heat contained in one pound of the steam in the products of combustion is 1,076 B. T. U., and in the 8.981 pounds of steam formed by burning one pound of hydrogen 9,664 B. T. U. The heat per pound of hydrogen, assuming that the water vapor in the products of combustion is not condensed, is, therefore, 62,032 — 9,664 = 52,368 B. T. U.

TABLE III.—*Heat of Combustion Reduced from Values Given by Julius Thomsen and Diminished by the Amount of Heat Carried off by the Water in the Products of Combustion.*

GAS.	Heat Per Molecule, By Thomsen.*	Molecular Weight.	Calories Per Kilogram.	British Thermal Units Per Pound.	Water Per Pound of Gas, in Pounds.	Heat in Vapor in B. T. U.	Net Heat Per Pound in B. T. U
Benzole vapor, C_6H_6.	797,530	77.844	10,245	18,441	.692	739	17,702
Propolene, C_3H_6.....	491,620	41.921	11,727	21,109	1.285	1,372	19,737
Olefiant gas, C_2H_4...	332,590	27.947	11,901	21,422	1.285	1,372	20,050
Carbon monoxide, CO	67,810	27.937	2,427	4,369	0	0	4,369
Marsh gas, CH_4	211,450	15.974	13,237	23,827	2.249	2,402	21,425

* These are obtained by multiplying the heat per molecule, as given by Thomsen, by $\frac{43.9}{44}$ in order to reduce them to the exact atomic weight. In his determinations the amount of gas burned was estimated by weighing the carbonic acid formed and the molecular weight of the latter considered to be 44, so that to reduce to exact molecular weights we have applied the above correction.

Favre and Silbermann's determination of the heat of combustion of hydrogen has been used in preference to that determined by Thomsen, as it is more nearly an average of the values determined by other experimenters than is the one given by Thomsen. The value given by Thomsen practically agrees with that of Andrews. Both these experimenters burned the oxygen gas in an atmosphere of hydrogen, whereas all other determinations, including those of Favre and Silbermann, were made by burning the hydrogen in an atmosphere of oxygen. Favre and Silbermann's value is only 0.8 per cent. greater than that given by Thomsen. In the deduction from

the experimental data given by Thomsen he disregards the latent heat of that portion of the water vapor that remains, together with the excess of hydrogen in the combustion chamber at the end of the experiment. The effect of the heat in this small amount of vapor influences the average figure he gives less than 0.2 per cent., but on applying it to the individual tests it makes the first one give nearly the same value as that determined by Favre and Silbermann. The total difference between the values given by Favre and Silbermann and Thomsen will not, however, affect the accuracy of any practical problem. The value given by Favre and Silbermann is a mean of six determinations, the highest and lowest of which differ from each other by 0.7 per cent.

PRESIDENT FRANCIS A. WALKER ON THE TRUE STANDING OF TECHNICAL SCHOOLS.

IN the *Educational Review* for October, 1891, there was published an article by President Walker, of the Massachusetts Institute of Technology, so admirable in its sentiments and expression that I would wish every reader of the INDICATOR to peruse every word thereof, and as the best means of securing this result I will quote the following passages which most conspicuously develop the leading ideas:

"Economists and people generally are so much accustomed to think of the more usual condition, in which demand creates supply, that they often forget, indeed, to many it never occurs, that there is another large class of cases, and these by far the most important of all, in which the opposite rule obtains. In the lower ranges of life, in matters of clothing, food, and shelter, and indeed in holding on to whatever advances civilization has once fairly and fully made, whether in material or in higher things, the conscious wants of humanity will, in all ordinary cases, suffice to secure the due supply, without any organized public or private effort other than that originating in personal interest. But in all things high and fine, and

generally also in every advance which material civilization is to make, there must be a better intelligence than that of the market, which shall apprehend, not what the people want, but what they ought to want. There must be disinterested efforts, on the part of the natural leaders of society, which shall secure, at whatever sacrifice, such a demonstration of the merits and advantages of the yet unknown thing, such a supply of the new good, as shall create the demand for it. It will not be until that want has been fairly and fully wrought into the public consciousness that the supply may thereafter be left to take care of itself.

"The American schools of technology illustrate, in an eminent degree, the law of human progress which I have stated. These schools did not come into existence in obedience to a demand for them. They were created through the foresight, the unselfish devotion, the strenuous endeavor, of a few rich men, and of many very poor men, known as professors of mathematics, chemistry, physics, and geology. At the time they came into existence there was a smaller demand for technically trained men than there is to-day, when for twenty-five years these schools have been pouring out their hundreds of graduates annually. That demand has been created by first furnishing the supply; by showing what young men properly educated and highly trained can do in organizing and directing the forces of American industry.

"That these schools—in spite of the fact that they had everything to do at once and little to do it with; in spite of the fact that they had no traditions to govern them, and had, indeed, the whole philosophy of their subject to evoke, *a priori;* in spite of general public indifference and even of much contempt—have done their work exceedingly well, even from the first, is fairly implied in the foregoing statement. It is truly remarkable that, with so little to go by and so much to do, all at once, out of such scanty means, there should have been so little waste of effort, so little done injudiciously, so few steps taken that needed to be retraced.

"But no one who thoroughly believes in the mission of schools of this class can be content merely to assert that the full time had come in the economic evolution of the nation when such schools were imperatively needed for the promotion of our industries, and that the institutions thus called into being have done this, their primary work, with triumphant success. I go far beyond this, and assert for these schools that they have come to form a most important part of

the proper educational system of the country, and that they are to-day doing a work in the intellectual development of our people which is not surpassed, if indeed it be equaled, by that of the classical colleges. No statement less broad and strong than this would begin to do justice to the view I take of what these schools are now doing, and are in an increasing measure to do for the manhood and citizenship of the country. I believe that in the schools of applied science and technology, as they are carried on to-day in the United States—involving the thorough and most scholarly study of principles directed immediately upon useful arts, and rising, in their higher grades, into original investigation and research—is to be found almost the perfection of education for young men. Too long have we submitted to be considered as furnishing something which is, indeed, more immediately and practically useful than a so-called liberal education, but which is, after all, less noble and fine. Too long have our schools of applied science and technology been popularly regarded as affording an inferior substitute for classical colleges to those who could not afford to go to college, then take a course in a medical or law school, and then wait for professional practice. Too long have the graduates of such schools been spoken of as though they had acquired the arts of livelihood at some sacrifice of mental development, intellectual culture, and grace of life. For me, if I did not believe that the graduates of the institution over which I have the honor to preside were better educated men, in all which the term educated man implies, than the average graduate of the ordinary college, I would not consent to hold my position for another day. It is true that something of form and style may be sacrificed in the earnest, direct, and laborious endeavors of the student of science; but that all the essentials of intellect and character are less fully or less happily achieved through such a course of study, let no man, connected with such an institution, for a moment concede!

"That mind and manhood alike are served in a pre-eminent degree by the systematic study of chemistry, physics, and natural history has passed beyond dispute. The haste with which the colleges themselves are throwing over many of their traditional subjects to make room for these comparatively new studies, shows how general has become the appreciation of the virtue of these, when combined with laboratory methods, as means of intellectual and moral training.

"I have spoken of the characteristic studies of the new schools as the best of all available means of both moral and intellectual training. I believe this claim to be none too broad.

"The sincerity of purpose and the intellectual honesty which are bred in the laboratory of chemistry and physics stand in strong contrast with the dangerous tendencies to plausibility, sophistry, casuistry, and self-delusion which so insidiously beset the pursuit of metaphysics, dialectics, and rhetoric, according to the traditions of the schools. Much of the training given in college in my boyhood was, it is not too much to say, directed straight upon the arts which go to make the worse appear the better reason. It was always an added feather in the cap of the young disputant that he had won a debate in a cause in which he did not believe. Surely, in these more enlightened days, it is not needful to say that this is perilous practice, if, indeed, it is not always and necessarily pernicious. Even where the element of purposed and boasted self-stultification was absent, there was a dangerous and a mischievous exaltation of the form above the substance of the student's work, which made it better to be brilliant than to be sound.

"Contrast with this the moral and intellectual influence of the studies and exercises I am considering. The student of chemistry or physics would scarcely know how to defend a thesis which he did not himself believe. In that dangerous art he has had no practice. The only success he has hoped for has been to be right. The only failure he has had to fear was to be wrong. To be brilliant in error only heightened the failure, making it the more conspicuous and ludicrous.

"How wholesome to the mind and heart of the pupil is such a regimen!"

These noble thoughts, so clearly expressed, should stir the heart of every reader.

HENRY MORTON.

THE ANALYSIS OF CYLINDER DEPOSITS.

BY PROF. THOS. B. STILLMAN.

THE deposits in steam cylinders, formed by the decomposition of lubricating oils, may be classified as simple or compound, depending upon whether the deposit is due to the decomposition of the oil alone or if foreign matters, carried over in the steam from the boilers, are also present.

In the former case, carbon, hydrocarbons, oils, and iron oxid are the principal constituents, whereas, in the latter, oleate of lime, carbonate of lime, and silica are often present in addition to the former.

The following analysis of a sample from a locomotive cylinder would indicate a simple deposit:

Moisture	2.28	per cent.
Oils soluble in ether { Animal	10.54	"
Oils soluble in ether { Mineral	11.23	"
Hydrocarbons insoluble in ether	47.97	"
Fixed carbon	23.73	"
Iron Oxid (FeO)	2.83	"
Undetermined	1.42	"
Total	100.00	

And the one given below, of a deposit from the steam cylinders of a large stationary engine, would show that scale forming material from the boilers had become a component.

Moisture	13.12	per cent.
Oils soluble in ether { Animal	8.15	"
Oils soluble in ether { Mineral	7.86	"
Soap	2.10	"
Hydrocarbons insoluble in ether	1.67	"
Fixed carbon	2.71	"
Oxids of iron (and aluminum)	6.81	"
Silica	3.65	"
Calcium carbonate	43.22	"
Magnesium carbonate	10.17	"
Undetermined	0.44	"
Total	100.00	

In many samples I have found copper and zinc in the deposits, formed by the corrosive action of the liberated oleic acid from the animal oil upon the brass or composition bearings.

This corrosive action is very marked where a poor quality of lubricating oil, composed of animal or vegetable oil, is used, whereas, a pure neutral mineral oil has no acid action at steam temperature. Oftentimes the statement has been made to me, when the deposit was given for analysis, "All of our lubricating oil is pure mineral oil; we use no other." And yet, upon analysis, lard oil would be shown in comparatively large amounts.

This is accounted for from the fact that while the consumer believes he is using pure mineral oil—which was sold to him as such—the manufacturer has introduced from 3 to 30 per cent. of lard oil.

A large majority of the so-called "pure mineral" lubricating oils for cylinder use contain at least 3 per cent. of animal oil; and it is the exception and not the rule to find a "pure mineral" oil for cylinder lubricating purposes.

An analysis of a deposit from the steam cylinder of a large freight steamer gave as a result:

Moisture		16.16	per cent.
Oils soluble in ether	Castor oil	26.19	"
	Mineral	32.50	"
Fixed carbon		7.92	"
Copper oxid		0.50	"
Iron oxid (FeO)		25.10	"
Undetermined		1.63	"
Total		100.00	

Pure mineral lubricating oil was supposed by the officers of the vessel to be the only lubricant used, and special care had been taken to secure it, but it appears that the engineer added a small amount of castor oil to the mineral oil, as, in his opinion, it made a better lubricant.

The decomposition of the castor oil and liberation of the fatty acid was the primary cause of the deposit.

The action of the fatty acids upon the iron and metal bearings results in different products. That is to say, while the copper when present has generally been estimated as copper oxid, the iron may exist only as oxid or as metallic iron, or both.

No doubt the oleic acid acts to form salts of these metals, but it is certain, in many instances, that when formed, they are immediately decomposed or partially so, and a resulting mixture formed that is somewhat difficult of analysis.

In the analysis here given, it will be noticed that the iron was found both as metal and as oxid.

Moisture		3.77	per cent.
Oils soluble in ether	Animal	21.27	"
	Mineral	19.60	"
Soap		traces.	
Fixed carbon		10.90	"
Iron oxid (FeO)		14.01	"
Iron		27.85	"
Lead oxid		0.82	"
Copper oxid		1.07	"
Undetermined		0.71	"
Total		100.00	"

The evolution of hydrogen by HCl, from the deposit, after all oils and fatty substances had been removed, indicated the presence of metallic iron, and the analysis of the residue, after the combustion of the fixed carbon, gave figures by which the ratio of Fe and FeO could be determined. A portion of the deposit, after extraction of oils by ether, is dried, then weighed, the hydrocarbons driven off by heat, and the amount of fixed carbon present converted by combustion with $H_2SO_4+CrO_3$ into CO_2 and weighed, this weight being calculated back to carbon.

Another portion of the same residue is ignited in a platinum crucible until the carbon is all consumed, then weighed. If the amount of carbon found is small and iron large, this weight may be larger than the original weight of the residue taken, owing to oxidation of metallic iron to Fe_2O_3.

Knowing the weight of carbon, and by making a determination of iron in another sample before ignition, the amount of FeO is easily found.

SCHEME FOR ANALYSIS OF CYLINDER DEPOSITS.

BY THOS. B. STILLMAN.

(1) Weigh out 10 gms. of the deposit upon a tared filter; dry at 102° C. to constant weight. Loss is moisture.

The filter and contents are transferred to a Soxhlet tube and exhausted with ether.

(2) *Residue.*—If qualitative analysis has shown soap to be present, the residue is dried slowly and then water poured upon the filter until extraction is complete.

(3) *Solution.*—Contains the free oils. Determine their weight by evaporation of the ether; then treat the residue with alcoholic solution of potash. Drive off the alcohol, treat the mass with warm water, transfer to a separatory funnel, allow to cool, add sufficient ether, agitate, and set aside six hours.

Draw off the soap solution.

(4) *Residue*—Dry; take a weighed portion; transfer to a weighed covered platinum crucible, and ignite gently; air excluded. The loss represents volatile hydrocarbons insoluble in ether. Determine this, then ignite at lowest possible heat until weight is constant. Accurate determination of fixed carbon requires oxidation with H_2SO_4 + CrO_3 to Co_2 and weighing as such, first treating with dilute HCl to drive off any carbonic acid united with CaO or MgO. Loss is fixed carbon. Residue contains the oxides of the metals, etc. The residue is weighed, then transferred to a porcelain capsule, HCl added with a few drops of HNO_3, and evaporated to dryness. Take up with HCl and water, filter; wash well.

(5) *Solution.* Evaporate to dryness and determine weight of soap. Separate the fatty acids and test qualitatively for animal and vegetable oils.

CO_2 is determined by taking a weighed sample of residue marked (4) treating with HCl and weighing the CO_2 evolved.

CO_2.

(6) *Residue.* Insoluble mineral matter. SiO_2, etc.

SiO_2.

(7) *Solution.*—Pass H_2S; filter.

(8) *Residue.* Sulphides of copper and lead. Separate and determine their amounts and calculate to oxides of copper and lead.

CuO. PbO.

(9) *Solution.*—Boil out H_2S, oxidize with HNO_3, add ammonia to strong alkaline reaction; filter.

(10) *Residue.* Fe_2O_3 (Al_2O_3) Dry, ignite, and weigh as such, and calculated to FeO. If qualitative analysis has shown iron, as metal, determine the Fe also.

Fe, FeO and (Al_2O_3)

(11) *Solution.*—Add H_2S to solution and filter.

(12) *Residue* ZnS Dissolve in HCl and determine zinc as carbonate and calculate to zinc oxide.

ZnO.

(13) *Solution.*—Boil out H_2S, add ammonic oxalate and a few drops of ammonic hydrate; set aside six hours; filter.

(14) *Residue* — CaO Ignite and weigh as CaO.

CaO.

(15) *Solution.* Add solution sodic phosphate; set aside two hours; filter, dry, ignite and weigh as $Mg_2P_2O_7$. Calculate to MgO.

Soap Solution. Warm gently for one-half hour, acidify with dilute H_2SO_4, allow separated fatty acids to collect and weigh with wax. Consult *Jour. Anal. & Applied Chem.*, Vol. V., page 710.

Animal oil.

Ether Solution Evaporate to dryness and determine weight of mineral oil. Test also for soaps insoluble in water, but soluble in ether (Lead soap, zinc soap, lime soap, etc.)

Mineral oil.

It is very seldom that SO_3 is found in cylinder deposits. If present, it can be determined by treating a sample of (4) with HCl, filtering, and estimating it in the filtrate.

Where qualitative analysis has shown the deposit to be a simple one, the analysis can be stated as follows:

Moisture	———	per cent.
Oils soluble in ether { Animal	———	"
Oils soluble in ether { Mineral	———	"
Hydrocarbons insoluble in ether	———	"
Fixed Carbon	———	"
FeO	———	"
Fe	———	"
Total	———	"

For a complex deposit, the following form can be used:

Moisture	———	per cent.
Oils soluble in ether { Animal	———	"
Oils soluble in ether { Mineral	———	"
Soap	———	"
Hydrocarbons insoluble in ether	———	"
Fixed carbon	———	"
Fe	———	"
FeO	———	"
CuO	———	"
PbO	———	"
ZnO	———	"
CaO	———	"
MgO	———	"
CO_2	———	"
SO_3	———	"
Silica, etc	———	"
Total	———	"

Where the CaO and MgO exist in amounts more than necessary to combine with the CO_2 and SO_3 present, the excess may have united with oleic acid to form soaps insoluble in water, but soluble in ether.

In some instances PbO and ZnO will be found only in the ether soap solution (3), as lead and zinc oleates, but in others, while they undoubtedly first existed as oleates, they had become decomposed, and the lead and zinc oxides would be found in section (8) of the above scheme.

BENDING TESTS OF TIMBER, ETC.*

BY PROF. J. BURKITT WEBB.

IN making transverse tests of beams of wood, cast-iron or any material that is not of uniform strength throughout, the work should be done in such a way as to secure the most accurate results with the least expenditure of labor and material.

The problem may present itself in the shape of *a* or *b*.

a. The quality of a large lot of beams is to be determined by the breakage of a number of specimens taken at random from the lot.

b. A small number of beams of a standard material are to be broken and the average strength of the lot determined.

In the first case economy requires us to determine the quality by breaking as few beams as possible, while in the second case the different tests should not be unnecessarily discordant and therefore of less value.

The problem may be treated mathematically as follows:

Let a beam which is of different strength in different places be represented by a beam of uniform material and of uniform depth, but of a width varying so that it shall have the same breaking moment at all points as the original beam. We shall call this the *geometrical* beam; if we regard the real beam as having a certain normal strength, except where there are weak places, the geometrical beam will be a parallel beam, with certain parts made thinner to represent the weak parts of the real beam.

Calling the width of the parallel part unity, let r be the width of a weak part, and therefore the ratio of the breaking moment at that place to the breaking moment for the parallel part.

To complete the notation, let l be half the length of a beam = half the distance between the two supports upon which it rests. Also let d be the distance from the center of the beam to either of two equal weights W resting upon it and producing the breaking moment

$$W(l - d).$$

When one weight $= 2\ W$ is hung in the center $d = 0$.

* Abstract of paper read at Rochester meeting of the Amer. Assoc. for the Adv. of Science, August, 1892.

To simplify the problem for presentation here we will suppose the lot of beams to have the same normal strength and the same value of r throughout, interrupted by but one short weak place in each beam, which may exist at any part of its length.

We propose now to show that the ordinary way of testing beams by loading them with a weight $2\ W$ at the center is uneconomical and unscientific, and that economy depends on the value of d.

The moment acting on the beam is uniform and $= W\ (l - d)$ at all points between the two weights; it decreases to o at the ends, however, being $= W\ x$ at any distance x less than $l - d$ from the ends.

It is evident that, if we could be sure of the weak place being exactly in the middle of the beam, there would be no objection to using one weight at the center, and we should arrive at the result desired—*viz.*, the least breaking moment for the lot of beams, by breaking that one beam. It is also evident that with two weights we need only be sure that the weak place lies between them, and that we are the more likely to have this condition in a beam taken at random as we make d greater.

By examining more carefully the case

$$d = o.$$

we find that, unless the weak place happens to come within the *limiting distance*

$$(1 - r)\ l$$

of the center, it will not cause the beam to fail, and that the *probability* of its coming within that distance is

$$(1 - r)$$

Therefore, the *probable number* of beams which must be broken to arrive at their minimum strength is

$$\frac{1}{1 - r}.$$

But an examination of the case of two weights, or

$$d = d$$

shows that the *limiting distance*, the *probability* and the *probable number* are, respectively,

$$(1 - r)\ (l - d) + d = (1 - r)\ l + rd;$$

$$(1 - r) + r\frac{d}{l} = \frac{l - rl + rd}{l} \text{ and}$$

$$\frac{l}{l - rl + rd}.$$

This last expression shows that when $d = 0$ the *probable number* depends entirely upon r, and that as r increases—*i. e.*, as the good quality of the beams is increased, the *probable number* increases to infinity for perfect beams. This is as it should be; for we should test an infinite number of perfect beams ($r = 1$) before finding a weak place. Suppose that $r = \frac{3}{4}$, say, then the *probable number* is 4, so that out of every four beams tested three are uselessly broken.

Suppose now that $d = \frac{1}{2}l$, then for $r = 1$ and $r = \frac{3}{4}$ we have for the *probable numbers* only

$$2 \text{ and } \tfrac{8}{3}.$$

But d need not be so large; supposing then that $d = \frac{1}{4}l$, the *probable numbers* will be

$$4 \text{ and } \tfrac{16}{7},$$

or, for $d = \frac{1}{8}l$,

$$8 \text{ and } \tfrac{32}{11}.$$

We see from this that for values of r ranging from three-quarters to one the number of beams saved by making $d = \frac{1}{4}l$ is from 12 out of every 28 to 28 out of 28, while for $d = \frac{1}{8}l$ it ranges from 12 out of 44 to 44 out of 44—or, in general, a saving of 25 per cent. and upwards in favor of testing with two weights instead of one, the saving showing in the decreased number of beams which must be broken to obtain a result of a certain degree of accuracy.

In cases where it may be desirable to employ the method by two weights without increasing the shearing effect of the weights a beam must be used one-third or one-seventh longer, according to whether $d = \frac{1}{4}l$ or $\frac{1}{8}l$, which makes low values of d preferable; but this lengthening is not necessary unless the limit of shear is reached and may probably there be avoided by an improved method of attaching the weights and supports.

The suitable value would then seem to be

$$d = \tfrac{1}{8}l \text{ to } d = \tfrac{1}{4}l.$$

A variable value of r has been considered with any number of weak places in a beam, and also the effect of the degree of precision required in results, but the outline above given is sufficient for presentation in this abstract.

ATHLETIC NOTES.

FOOTBALL.—Schedule of games arranged for 1892 :

Oct. 1, Orange A. C. *vs.* Stevens, at Orange ; score, 4-4.
" 6, Crescent " " " " Hoboken ; score, 10–4.
" 8, Manhattan A. C. *vs.* Stevens, at Polo Grounds ; score, 4–6.
" 12, Wesleyan " " " Middletown ; cancelled.
" 15, New York A. C. " " " Polo Grounds ; score, 6–10.
" 21, Varunas, " " " Paterson ; cancelled.
" 22, U. S. Military Academy *vs.* Stevens, at West Point ; score, 42–0.
" 25, New York A. C. *vs.* Stevens, at Hoboken ; cancelled.
" 27, Fordham " " " score, 0–22.
Nov. 2, Rutgers " " " score, 6–22.
" 5, Rensselaer Polytechnic Institute *vs.* Stevens, at Troy.

A return game will also be played later in the month with Rutgers.

The above is the schedule for football, arranged for this season by Mr. Corbett, '95, Manager, and Mr. Coyne '94, Captain. It will be noticed that there are no games with any of the colleges in the old league—namely, Dartmouth, Williams, Amherst and Boston Tech. This was dissolved last fall, owing to the refusal of the first three to elect officers for the following year. It may be a disappointment to some to find these old ties broken, but the INDICATOR cannot think that the result will be a loss in the interest in the game at Stevens. To belong to the old league was very well years ago when the work was less severe than now, and men could spare time to practice for the games. At the present time, however, it seems to be impossible for our men to compete successfully with colleges of more leisure, and still maintain the necessary standing in their studies.

Another consideration lies in the fact that there was no common interest or rivalry to bind the members of the old league together. Stevens especially had nothing to do with them, beyond the yearly football games. Under these circumstances it is not a matter of surprise that interest in the championship waned while the long and expensive trips told heavily upon our financial resources.

The proper place for Stevens lies in a league of local colleges. This would mean short and inexpensive trips, games on the home grounds, and a sharp rivalry with correspondingly increased interest. There is plenty of material for such a league, and the time seems ripe for its formation. Now that we are free why should not Stevens take the lead and agitate the question.

As regards football at the 'Stute the work done so far this year has been of a very encouraging nature. With a good man as manager and an able captain interest in the game has been largely revived.

Captain Coyne is an enthusiast, and has managed to infuse a large part of his enthusiasm and energy into his men. He has succeeded in

putting a strong team into the field (the strongest, perhaps, that has represented Stevens for several years), in getting out a large, hard-working scrub, and attracting a large and interested crowd of spectators to the daily practice. The work of the team, however, is not yet what it should be. The men are still slow in lining up and putting the ball in play, and, worst of all, they are careless in following the ball, and the heavier men show an almost irresistable tendency to tackle around the neck. The interference also is weak, being slow in getting off, and too easily broken up. The team has been working hard daily to correct these faults, but is hampered by the lack of a competent coach to direct their efforts. If Stevens could but secure this for her football team, as she has for her lacrosse team, it could not fail to make a great difference.

The INDICATOR has only this one criticism to make upon the style of game played. If the backs would play a little further away from the rush line they could get a better start; and while it may be profitable to bring in the ends for a run around the line, when playing weak teams, the West Point game would seem to prove it poor policy against a stronger one. Princeton tried it against Yale last year, and it apparently not only made her slow in getting started, but allowed Yale to surround and break up the interference before the runner and his guards could get clear of the line.

Notwithstanding these drawbacks a vast amount of good work has been done, the result of which will be noticed even more next year than it has been this. It is, therefore, with regret that we receive the announcement that the team must go out of training after the Troy game on the 5th. The men have given so generously of their time that they have become seriously inconvenienced in their studies, and the lost ground must be regained soon if we expect to keep our football contingent till another year.

STEVENS, 4; ORANGE ATHLETIC CLUB, 4.

The first game of the season was played against the Orange A. C. upon their grounds. Stevens showed the good results of her short training and put up the better game, having the ball close to the Orange line each time when time was called. The teams lined up as follows:

Orange.		*Stevens.*
Strong	Left end	Brown.
Thorpe	Left tackle	Hutchinson.
Kemble	Left guard	S. C. Mackenzie.
Carter	Center	Gallaher.
Webb	Right guard	Lord.
Burdick	Right tackle	Lançon. / Schumacher.
Mowry	Right end	Coyne (Capt.).
De Hart (Capt.)	Quarter	Griswold.
Minot	Left half back	W. P. Mackenzie.
Leakin	Right half back	MacCord.
Marshall	Full back	Maynard.

The first goal was scored by Brown in 10 minutes. Toward the end of the half Burdick scored for Orange on Maynard's fumble of Marshall's punt. Brown backed the center well, and Maynard and Mackenzie made

several good runs. The ball was, however, fumbled too frequently, and the interference very ragged at times.

STEVENS, 0; CRESCENT A. C., 10.

The second game was played on the home grounds with the strong team of the Crescent A. C., and was watched by a large and interested crowd. Our boys showed much improvement in their play, and held the score down well. The old faults of fumbling and keeping track of the ball was painfully apparent during the first half. During the second half the team took a decided brace and nearly succeeded in scoring, time being called with the ball on the Crescent's five-yard line.

The teams were:

Crescent.		*Stevens.*
Fish, Culver	Left end	Brown.
Fitzgerald	Left tackle	Hutchinson.
Robertson	Left guard	C. Mackenzie.
M. J. Lamarche	Center	Gallaher.
Palmer, Baldwin	Right guard	Lançon, Schumacher.
Brown	Right tackle	Cuming, Kenyon.
G. Wingate	Right end	Brown.
Beecher	Quarter	Griswold.
Slayback, Stockton	Left half	Cuming, Fielder.
Fauss	Right half	P. Mackenzie.
Sheldon	Full half	Maynard.

The first touch down was made by Slayback in nine minutes on a clean break through the line. Just before time was called Wingate secured the ball from a scrimmage and made the second down, Slayback kicking goal.

STEVENS, 10; NEW YORK A. C., 6.

The teams were:

Stevens.		*N. Y. A. C.*
Koehler, Fielder	Left end	Turner, Warner.
Hutchinson	Left tackle	Kottman.
McIllwaine	Left guard	Sleziner.
Gallaher	Center	Palmer.
Schumacher	Right guard	Arnton.
Cuming	Right tackle	Luison.
Coyne	Right end	Schumacker.
Griswold	Quarter	Brett.
Mackenzie	Left half back	O'Connor.
Brown	Right half back	White.
Maynard	Full half back	Wurtemberg.

First half.—Touch downs, Maynard, 1; Brown, 1; goals kicked. Mackenzie, 1. Score, Stevens, 10; N. Y. A. C , 0.

Second half.—Touch down, Wurtemberg, 1; goal kicked, O'Connor, 1, Score, Stevens 0; N. Y. A. C., 6. Total, Stevens, 10; N. Y. A. C., 6.

STEVENS, 0; WEST POINT, 42.

The game was played upon the parade ground at the "Point," and was witnessed by some 160 students who accompanied the team up in special cars. It was a foregone conclusion that the cadets would win, as their team was known to be remarkably strong, but the size of the score was the cause of considerable disappointment. Notwithstanding this, the men played grittily. Our men made their presence known by their steady cheering, and thoroughly enjoyed themselves. The most cordial feeling prevails between our boys and the cadets, and the game with them bids fair to become an annual and most enjoyable custom. If anyone wants to know how a Stevens man acts when relieved from care, just let him go up on the cars and see for himself.

Stevens did some bad fumbling, and the men were slow in following the ball, and did not interfere well. The work of our team was not up to the usual standard; still, it must be borne in mind that they were outclassed by the West Pointers. Their team is exceedingly strong both on the line and back of it, and the playing is sharp, vigorous and effective. Their first game, when they outplayed Wesleyan, gave a good indication of the strength they will be able to develop in time. For Stevens, Maynard and Coyne did specially well, and Timberlake, the brilliant half back, deserves mention for West Point.

The teams lined up as follows:

Stevens.		*West Point.*
Koehler	Left end	B. Ames.
Hutchinson	Left tackle	Houle.
McIllwaine	Left guard	Laws.
Gallaher	Center	T. L. Ames.
Marshall	Right Guard	Clark.
Cuming	Right tackle	Aultman.
Coyne (Capt.)	Right end	Stacy. / Smedburg.
Fielder / Paulsen	Quarter	Stout
Brown	Left half back	Timberlake.
P. Mackenzie	Right back	King.
Maynard	Full half back	Pattison.

Score.—First half	Stevens 0	West Point	28
Second half	" 0	" "	14
Total	0		42

Touch downs, by Pattison, 3; Clark, 1; Ames, 1; Timberlake, 2. Goals kicked, Pattison, 6. Safety, Stevens, 1.

INSTITUTE NOTES.

The Chemical News, issue of July 22, 1892, contains a review, by the editor, Prof. William Crooks, F. R. S., upon the book issued by the Alumni of Stevens Institute, entitled "Biographical Sketch of President Henry Morton," from which a few extracts will not be inappropriate.

"We have here a graceful tribute paid by his colleagues and pupils to a *savant* of distinguished merit. * * * President Morton has long been recognized as the foremost scientific expert in New York in patent litigations and in similar cases. It must be remarked that in the United States, despite the careful examination instituted before granting a patent, disputes as to the validity, the proprietorship, and the scope of a patent, seem not less frequent than in Britain.

"We do not know whether the attention of Professor Morton was ever drawn to the necessity of altering the present system of taking scientific evidence, and of making the expert the assessor of the Court, instead of the witness 'called' by either party and treated by the other as a kind of informal advocate.

" * * * A paper which appeared in 1879 (*Chemical News*, Vol. XXXIX., p. 255), treats of 'the chronology of the isomeric purpurines and the actual relations of some of the bodies which have been called anthropurpurine, isopurpurine and flavopurpurine.' There seems good reason to conclude that he was the first to isolate and recognize flavopurpurine.

"He is one of those who eschew the error of explaining physical facts by ultra-human agencies. At the same time we may be pardoned for remarking, and as he shows very ably in a paper on 'The True Relations of Physical Science to Religion' (STEVENS INDICATOR, 1888, Vol. V., p. 158), he insists that science and religion can neither directly support nor refute each other.

"It is interesting to note that whilst Professor Morton is highly esteemed as an original investigator, as a lecturer, and as an educational organizer, he is no less appreciated among a wide circle of friends, among his colleagues and pupils for his unvarying courtesy and kindness.

"We hope that Professor Morton may long survive to exert his varied talents and to promote the scientific culture of his country."

OPERATIONS TO EXTEND the Institute buildings will probably not be commenced until next summer.

The need for more room, on account of the division of the Freshman Class into two sections, was greatest in the workshop and drawing departments. The addition of new tools in the shop has, however, enabled this department to handle the increased number of students, and as it was possible to arrange the roster so that the lower classes do not draw at the

same hours of the day, there is no difficulty in accommodating the classes in the drawing rooms.

In case of a division of the Sophomore Class, which seems likely next year, additional accommodations will be absolutely necessary, as besides the pressure in the above-mentioned departments the need of more room in the chemical laboratory will have to be relieved also.

THE NUMBER OF STUDENTS enrolled as members of the Institute this year is 268 or about 50 more than a year ago.

The Freshman Class, which numbers 108 members, was selected from 125 applicants, and is larger by 28 members than any previous entering class.

The Sophomore, Junior and Senior Classes number respectively 64, 52 and 44 members.

The Freshman Class is, for the first time, divided into two sections in all the departments which the class attends.

This has necessitated the appointment of additional instructors. Mr. S. D. Graydon, '75, has been appointed Assistant Professor of Drawing, and Mr. L. B. Corbett, M. E., '92, has been assigned to the Drawing Department as Graduate Assistant. Mr. Graydon and Mr. Corbett succeed Mr. H. F. Cuntz,'87, and Mr. Wm. J. Beers,'89, who resigned their positions as Graduate Assistants. Mr. Geo. L. Manning, M. E., '91, has been assigned, as instructor, to the Departments of Chemistry and Physics. Mr. R. M. Anderson, M. E., '87, instructs one section of the Freshman Class in mathematics and is also instructor in the Department of Experimental Mechanics as heretofore.

Professor Kroeh no longer instructs in the Stevens School, his time being fully occupied by the Institute classes.

The class of '96 has the following membership:

J. P. A. Badenhausen, Hoboken, N. J.	Roger Chew, Charleston, W. Va.
Geo. E. Baldwin, Nyack, N. Y.	C. R. Christy, Jr., Stamford, Conn.
F. M. Bennet, East Orange, N. J.	J. L. Christy, Stamford, Conn.
H.T. Bernhard, Jr.,W. Hoboken,N.J.	Ferd. Cimiotti, Verona, N. J.
H. W. Biddle, New York City.	B. C. Clark, New York City.
J. B. Blair, New York City.	Chas. F. Collyer, New York City.
Wm. J. A. Boucher, Jersey City, N. J.	R. A. Cowles, New York City.
F. G. Brandes, New York City.	L. W. Colquitt, South Orange,N.J.
R. E. Brückner, Hoboken, N. J.	F. A. Culbert, Jersey City, N. J.
Fred. Bull, New York City.	F. A. Curtis, Mount Vernon, N. Y.
Bradford Bumsted, Jersey City Hgts.	W. E. Denton, Roselle, N. J.
E. E. Burnet, Madison, N. J.	W. H. Dickerson, Newark, N. J.
W. S. Burnett, Brooklyn, N. Y.	Chas. Duehring, Philadelphia, Pa.
D. S. Bushnell, Morristown, N. J.	Jno. P. Evertsz, Curacao, W. I.
S. F. Butterworth, Morristown, N. J.	Arthur Fagan, Rahway, N. J.
Edward Campbell, Orange, N. J.	J. B. Faulks, Jr., Jersey City, N. J.
F. R. Chambers, Jr., New York City.	A. J. Foley, Galveston, Tex.
M. H. Chapin, Brooklyn, N. Y.	Celestino Garcia, Puntal, Oviedo Sp.

J. D. Gedney, East Orange, N. J.
Geo. F. Gilmore, New York City.
Walter Grempler, Hoboken, N. J.
A. W. Gunnison, Brooklyn, N. Y.
Henry Guttin, New York City.
A. S. Hamilton, Albany, N. Y.
H. M. Hardie, New Orleans, La.
L. H. Hardie, New Orleans, La.
F. R. Harris, New York City.
Jno. R. Hasbrouck, New York City.
George Hewitt, Paterson, N. J.
H. L. Holbrow, New York City.
S. Hollingsworth, Scotch Plains, N. J.
Chas. H. Hunt, Brooklyn, N. Y.
T. F. Hussa, Jersey City, N. J.
Geo. M. Jacob, Brooklyn, N. Y.
W. H. Jennings, Jr., S. Orange, N. J.
John Kearney, Edgewater, N. Y.
Frank Kennedy, Cumberland, Md.
R. T. Kingsford, Jersey City, N. J.
George Kollstede, New York City.
Jno. B. Kreischer, New York City.
Geo. L. Lanson, Rutherford, N. J.
Robert Leber, Hoboken, N. J.
Chas. A. Louis, New York City.
T. J. Main, Hoboken, N. J.
H. C. Mathey, Hoboken, N. J.
Wm. C. Maul, East Orange, N. J.
Jos. P. McLean, Jersey City, N. J.
H. W. Mercer, Brooklyn, N. Y.
H. C. Messimer, Calumet, Mich.
R. L. Messimer, Calumet, Mich.
A. B. Miller, Montclair, N. J.
Wm. C. Morris, Jersey City, N. J.
Chas. S. Mott, East Orange, N. J.
Chas. L. Newell, South Orange, N. J.
H. D. Nitchie, Brooklyn, N. Y.
W. B. Osborn, Yonkers, N. Y.
F. F. Overton, Peconic, N. Y.
Chas. F. Patterson, Roselle, N. J.
Charles Peck, Brooklyn, N. Y.
Frank Plum, Rahway, N. J.
O. A. Pope, East Orange, N. J.
S. F. Randolph, Jr., Brooklyn, N. Y.
Wm. T. Rasmus, Brooklyn, N. Y.
P. F. Reichhelm, Jersey City, N. J.
W. C. Roome, Jersey City, N. J.
W. J. Rusling, Jr., Newark, N. J.
J. S. Satterthwaite, New York City.
J. Schimmel, Jr., Orange Valley, N. J.
A. S. Schweizer, New York City.
Leon'd Seeligsberg, Hoboken, N. J.
Martin Shepard, New Orleans, La.
A. de Los Smith, New York City.
Jas. H. Stearns, Brooklyn, N. Y.
H. A. Steinhauser, New York City.
P. N. Strong, Savannah, Ga.
H. R. Summerhayes, San Antonio.
Chas. B. Tarr, New York City.
A. C. Tate, New York City.
E. M. Toby, New Orleans, La.
A. F. Van Winkle, Paterson, N. J.
Ray Volkmar, Menlo Park, N. J.
C. E. Vreeland, Newark, N. J.
P. D. Wagoner, Somerville, N. J.
A. E. Weichert, Hoboken, N. J.
A. E. Whitman, Brooklyn, N. Y.
A. H. Wilkens, Hoboken, N. J.
A. L. Wilson, New York City.
A. J. Wood, Boonton, N. J.
Victor Wood, Hoboken, N. J.
C. G. Woolson, Newark, N. J.
C. R. Youngs, Summit, N. J.

THE FOLLOWING IS AN EXTRACT from an article on the Stevens Institute of Technology which appeared in London *Engineering*, July 15, '92:

"It is a well-known fact that students from the American technical schools find it much easier to get employment than those in a similar position in this country do. In fact, American manufacturers are glad to get them, while here employers almost make a favor of taking them, even at a salary of 'nothing a week and find themselves.' Such a condition of things is a flattering tribute to the excellence of the course of training pursued at the American technical schools. The first of these schools to be established was the Stevens Institute of Technology, at Hoboken, N. J

This was founded about the year 1870 by Mr. Edwin A. Stevens, who gave a sum of $750,000 for this purpose. In commencing such an enterprise, the Trustees who administered Mr. Stevens' munificent gift had the good fortune to secure the co-operation of Professor Henry Morton, who accepted the post of President of the institution. Professor Morton was at that time resident Secretary to the Franklin Institution, and had already acquired a reputation as an experimentalist of great originality, and as a most brilliant and interesting popular lecturer on scientific subjects. At the same time he held very advanced views on the subject of education, and advocated the abandonment of the traditional methods of learning entirely from books, and the substitution for this of practical work in the laboratory. Such has been the success of the students thus trained that the Stevens Institute can now find accommodation for only about 60 per cent. of those applying for admission, in spite of the fact that Professor Morton has spent a large portion of his private fortune in endowing the college with additional workshops and laboratories. In fact, his various gifts to the institution during the past 16 years have amounted to over $50,000. An attempt is now being made to increase the accommodation, so as to be able to take in a larger proportion of the applicants than can now be admitted, and to this end former students have raised between them a sum of $20,000, to which Professor Morton, with characteristic generosity, has added an equal sum. Much more, however, is required, but among the numerous wealthy manufacturers of the United States there should be little difficulty in finding the money needed, particularly when it will be expended in a manner calculated to benefit in so direct a fashion their commercial and manufacturing interests.

"The practical character of the training given is assured by the choice of the professors. Thus when we mention the name of Dr. Coleman Sellers as one of the lecturers on mechanical engineering, many experienced engineers will envy the students of this fortunate institution their great advantages in having, as a teacher, a man of such varied and extensive practical experience.

"We notice also that most American technical schools publish journals. Attempts have been made to do the same thing in this country, but in the instances which have come under our notice these publications have died from inanition after a more or less protracted struggle for existence. We note, however, one feature in the American publications which may go to explain their flourishing conditions; that is, that the professors at these institutions appear to be large contributors, while here the journals are run entirely by the students. Thus in a number of the STEVENS INDICATOR, now before us, and selected entirely at random, only one of the papers published out of a total of seven was due to present students of the Institute. This practice appears very sensible, as a student at a technical college is not likely to have information of any great value to communicate, as most of what he knows must, in the nature of things, be second-hand. Exceptions do occur, of course, where, as is now frequently the case, the students are engaged in research work, under the guidance of their pro-

fessors. Considering the excellent work the Stevens Institute has done in the past, we can only hope its field of usefulness will not be contracted by a lack of funds, and we wish Professor Morton and his former pupils every success in their endeavor to enlarge and improve the facilities for a sound education in the principles of engineering at Hoboken."

THE FOLLOWING PAPERS were presented at the Rochester meeting of the Amer. Assoc. for the Advancement of Science, August, 1892:

"Negative Specific Heats," by Prof. De Volson Wood; "Bending Tests of Timber," by Prof. J. B. Webb; "Method of Measuring Loss of Power and Drop of Pressure between Cylinders in Multiple-Cylinder Engines," by Prof. J. E. Denton; "Measurements of Total Heats of Combustion. Use of Anemometers for Measuring Velocity of Air in Mines," by Prof. D. S. Jacobus; "Steam Economy of the Engines of the Screw Ferryboat 'Bremen,'" by Profs. J. E. Denton and Jacobus; "Relative Economy of the Single-Cylinder Air Compressor with Cooling by a Spray of Water, and the Present Economy of the Compound Compressors at Qua de la Gare, Paris, France," by Fred. T. Gause, M. E., '91.

PRESIDENT MORTON and Professor Denton attended the banquet given in honor of Mr. John Fritz, the retiring Superintendent of the Bethlehem Iron Works, Bethlehem, Pa., on Wednesday, September 28. Mr. Fritz, who has been connected with these works for many years, and now retires from active life, is well known for his engineering achievements; to him is due, in a large measure, the success of the above plant.

Many prominent engineers, members of the Engineers' Club of New York City, were present at the complimentary dinner and at the reception following.

PROFESSORS WOOD, WEBB, LEEDS AND JACOBUS attended the Rochester meeting of the American Association for the Advancement of Science, held in August.

An account of the proceedings of the Mechanical Section of this Association was published in the issues of the *American Machinist* of October 13 and 20.

PROFESSOR KRŒH has been engaged during the summer months in writing three text-books on "The Living Method for Learning How to Think in French, in German, and in Spanish." The French book will be issued shortly, and the manuscript for the German and Spanish books is nearly complete.

These books illustrate the most advanced thought as to the best method of acquiring a speaking acquaintance with a language, and will be well adapted for the language courses in high schools and colleges.

"MECHANICAL DRAWING" is the title of Professor MacCord's latest book, which has just been issued by Jno. Wiley & Sons.

The second part of this book has been previously published under the title "Practical Hints for Mechanical Draughtsmen;" the first part consists of a series of drawing exercises comprising the course pursued in the

Freshman year at the Institute. The whole is designed to be used by the student as a book of reference, and will be found a valuable aid in the performance of the work of the course in the Department of Mechanical Drawing. The complete title of the book is "Mechanical Drawing, Progressive Exercises and Practical Hints for the Use of All who wish to Acquire the Art with or without the Aid of an Instructor."

IN A SHORT ARTICLE entitled "The Science of Smelling," contributed by Professor Wood to *Science*, of October 14, 1892, he advances as a probable theory that the sensation of odor is produced by undulations of an ether which emanate from bodies and are transmitted to the sensitive nerves of the olfactories.

He also suggests that the physiological qualities of the olfactories would furnish a field for the most delicate and refined investigation.

PROFESSOR JACOBUS WAS ELECTED Secretary of the Mechanical Section of the A. A. for the Advance of Science, at the meeting held at Rochester, N. Y., last August.

AT THE REQUEST of Professor Denton, Mrs. Corliss presented the Institute with an excellent large size photograph of her husband, the late George H. Corliss, of Providence, R. I. It will be added to the Library collection of portraits of eminent engineers, to which several contributions have already been made by the Alumni Association.

THE INSTITUTE HAS RECEIVED, from the Southwark Foundry and Machine Company, of Philadelphia, two large phototypes, one representing a centrifugal plant driven by compound condensing Porter-Allen engines, and the other ten blast furnace blowing engines. These machines were built for the Illinois Steel Company's works, located at South Chicago, Ill.

THE CLASS ELECTIONS for the year 1892-'93 have resulted as follows:

Senior Class. — President, Percy Mackenzie; Vice-President, B. G. Braine; Secretary, B. A. Inglis; Treasurer, Anson Wilbor; Historian, E. R. Douglas.

Junior Class.—President, G. P. Hodgeman; Vice-President, A. M. Lozier; Secretary, J. M. Cox; Treasurer. J. B. Hamilton; Historian, E. P. Buffet.

Sophomore Class.—President, E. Hutchinson; Vice-President, R. T. Walker; Secretary, E. Jewell; Treasurer, C. Paulding; Historian, Edmund Kemble.

Freshman Class.—President, Louis Hardie; Vice-President. J. B. Faulks, Jr.; Secretary, J. S. Satterthwaite; Treasurer, R. Brückner; Historian. F. Chambers.

COLLEGE EXECUTIVE COMMITTEE.—A short time ago the different classes in the Institute appointed committees to confer together and discuss the advisability of forming some body which should have power to call mass meetings of the students, represent them before the Faculty, and in general take the lead in dealing with disputed college affairs.

This committee, consisting of Messrs. P. Mackenzie, A. E. Merkel and J. F. Paulsen, '93; W. B. O. Field, A. M. Lozier and F. J. Angell, '94; G. S. Montgomery, L. Carter and T. B. Cumming,'95; and D. S. Bushnell and J. S. Satterthwaite,'96, after carefully discussing the question, in the light of the customs now in vogue at other colleges, agrees upon the need of such a body, and has made the following report:

Resolved, That this committee report to the undergraduates of the Institute the following suggestions as the result of their deliberations:

First.—That college matters could in general be more expeditiously and justly settled by a committee of the undergraduates than in mass meetings.

Second.—That this committee should consist of four Seniors, four Juniors, two Sophomores, two Freshmen, and one Alumnus who should be its Chairman, and preside at mass meetings when necessary.

Third.—The powers of this committee should be to decide all strictly college affairs, and decide any other matters which may be referred to it.

Fourth.—To represent the undergraduates as a whole before the Faculty.

Fifth.—Its meetings should be open to all students.

Sixth.—That these recommendations should go into effect upon being approved by three classes.

Resolved, That copies of these recommendations be drawn up by the Secretary and presented to the classes for action by the several committees.

Resolved, also, that copies be posted upon the college bulletin and published in the *Stevens Life* and STEVENS INDICATOR.

A. E. MERKEL, *Chairman.*
A. M. LOZIER, *Secretary.*

INSTITUTE PERSONALS.

'75.

I. N. KNAPP is located with the Omaha Gas Manufacturing Company, Omaha, Neb.

'76.

GUS. C. HENNING was married to Miss Fanny Funk on Thursday, September 1, 1892.

WM. KENT has removed his office from the *Times* Building to 35 Warren Street, New York City.

A. R. WOLFF will lecture before the Franklin Institute, of Philadelphia, on Friday, February 3. Subject of lecture to be announced later.

'77.

L. H. NASH's permanent address is First Avenue and Forty-second Street, Brooklyn, N. Y.

'78.

BROWN AYRES, Professor of Physics and Electrical Engineering, at Tulane University, New Orleans, La., was elected to full membership in the Amer. Institute of Electrical Engineers at the March meeting.

'79.

MAUNSEL WHITE, of the Bethlehem Iron Company, Bethlehem, Pa., recently prepared for *The Railroad Gazette*, and had published in its issue of September 2, 1892, an interesting report giving the results of an analysis of a steel rail which, during a 21 years' term of service on the N. Y., N. H. & H. R. R. R., had given most excellent results.

'82.

CHAS. W. SCRIBNER, who has occupied the Chair of Mechanical Engineering at Ames Agricultural College since 1887, has recently been appointed Professor of Mechanical Engineering in the University of Illinois, Champaign, Ill.

'84.

WM. S. ALDRICH has resigned his position as Associate in Mechanical Engineering in Department of Electrical Engineering at Johns Hopkins University to take position of Assistant Superintendent with the Wm. H. Harris Steam Engine Company. of Providence, R. I.

Mr. Aldrich was elected an Associate Member of the American Institute of Electrical Engineers in March, 1892.

ALEX. J. WURTZ read a paper on "Lightning Arresters and the Discovery of Non-Arcing Metals" at the March meeting of the American Institute of Electrical Engineers.

Considerable interest was manifested in this paper, and it was extensively discussed, among others, by Mr. Wetzler, '82, Mr. E. P. Thompson, '78, and Mr. E. T. Birdsall, '86.

'85.

WM. N. STEVENS is with Will W. Bierce, manufacturer of Taylor Cotton Compressor, Montgomery, Ala.

AFTER AN ILLNESS of two weeks Paul G. Hussey died of typhoid fever at his home in Brooklyn, N. Y., on Wednesday, October 12, 1892.

'88.

ALTEN S. MILLER is Manager of the National Gas Light and Fuel Company, builders of water gas works, 52 Lake Street, Chicago. Ill.

WILLIAM WHIGHAM is with the Carnegie Iron and Steel Company, Homestead Mill, Homestead, Pa. Permanent address, Camden, Pa.

'89.

JAMES H. SCOTT is a member of the firm of Chamberlin, Delaney & Scott, proprietors of a foundry at Richmond, Va.

CHAS. P. BENNS has been appointed instructor in the Manual Training School at Providence, R. I.

WM. D. HOXIE was married to Vinnie Louise Brown on Wednesday, October 19, 1892, at the Calvary Baptist Church, Elm Street, Westerly, R. I.

'90.

SAM'L F. SMITH is the First Assistant Engineer of Estate Consuelo, San Domingo. His address will be care of S. P. de Macoris, San Domingo.

'91.

BENJAMIN W. CARLL is employed as inspector for the Lancashire Insurance Company, 45-49 Cedar Street, New York City.

GEORGE F. SUMMERS is in the employ of the National Gas Light and Fuel Company, 52 Lake Street, Chicago, Ill.

HENRY A. WOLCOTT is draughting for the Link Belt Engineering Company, 49 Dey Street, New York City.

LOUIS E. ELSON is a draughtsman in the office of Chas. B. Brush, C. E., Hoboken, N. J.

A. P. BOLLER, JR., who is with H. R. Worthington and has been located at St. Louis, Mo., is now stationed at the Hydraulic Works, South Brooklyn, N. Y.

'92.

E. D. LITCHFIELD is in the employ of the Gould Coupler Company, Buffalo, N. Y.

CARL H. HOTOPP is with the Illinois Steel Company, South Chicago, Ill.

PHILIP VIDAL is draughting for the Camden Iron Works, Camden, N. J.

PIERSON L. WELLS is draughting for Post & McCord, bridge builders, 102 Broadway, New York City.

LOUIS WAFELAER, JR., is located in the shops of the Louisville and Nashville Locomotive Works, Louisville, Ky.

H. D. KING AND W. B. POWELL are associated as The King Engineering Company at 136 Liberty Street, New York City. They will make a specialty of testing steam and electric plants, will furnish designs of new machinery and do general draughting.

MR. OSCAR C. WHITNEY, '92, is with the Safety Car Heating and Lighting Company of New York, who control the "Pintsch System" in America. He is at present employed in Philadelphia, where they are putting up gas works for the Philadelphia and Reading Railroad.

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THE WHITEHEAD TORPEDO.

BY F. M. LEAVITT, M. E., '75.

THE Whitehead belongs to that type of torpedo known as "automobile," in contradistinction to the type called "controllable." When of the former class, the torpedo is discharged from a tube by means of a light powder charge, or by compressed air; and, after striking the water, which it does within a few yards of the launching tube, is propelled on its course and its movements controlled entirely by its own mechanism. In the "controllable" type, permanent communication is maintained during the run between the torpedo and the launching station, through one or more wires, which the torpedo unreels as it proceeds, and by means of which its movements are electrically controlled by an operator at the station. This type of torpedo is especially adapted for harbor and coast defense, while the "automobile" has a much wider range of action, as it can not only be effectively used in this work, but it is also a formidable weapon of attack by battleships, cruisers and torpedo boats.

The fundamental aim in all torpedoes used as weapons in naval warfare, is to attack the enemy's vessel below the water line, thus

taking him where he is weak and unprotected by armor, and where a wound will be most certainly disastrous.

While a number of automobile torpedoes have been devised, the Whitehead is the only one which may be said to have advanced beyond the experimental stage; and it is the one in use by all the Governments of the world which make any pretensions to a navy, with the exception, until now, of the United States. Recently it has been adopted by our Navy Department; and, out of a hundred for which an order has been placed, five have already been delivered, 30 additional are ready for service trial, as soon as the weather permits in the spring, and the remaining 65 will be completed before the end of this year.

The dimensions of the torpedoes being built for this Government are: length, 11 feet 8 inches; diameter, about 17.7 inches (45 centimeters); and weight, when charged with 120 pounds of gun-cotton, and ready for firing, about 830 pounds.

The head, which contains the explosive charge, is attached to the middle body by screws, and is made of sheet metal about one-sixteenth inch thick, spun up to the shape shown in the cut. To explode the charge, a cartridge is inserted in the nose, in which is placed a percussion cap or primer; and forward of this is a firing pin, which is driven back against the primer by contact with any obstacle in the path of the torpedo. In order to avoid premature explosion, through accident in handling, the firing pin is securely held out of contact with the primer by a traveling nut. This nut is made to revolve, as the torpedo passes through the water, by a small fan wheel or propeller, which is shown at the forward end of the cut, so that when the torpedo has run 50 or 60 yards, it is set into position for firing upon contact.

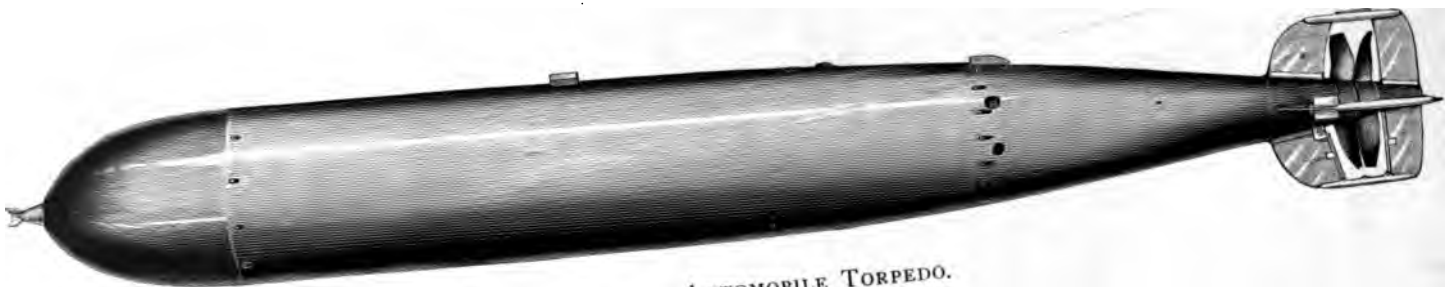
The middle body, for a length of about 5 feet, is three-eighths of an inch thick, and forms a reservoir, in which is stored air at a pressure of 1,350 pounds per square inch. This air constitutes the motive power for propelling the machine. The reservoir is a forged tube, without seam or weld, and made of steel of very high tensile

strength. The heads are screwed in and the joints soldered. Each reservoir is tested by hydrostatic pressure to 2,025 pounds per square inch.

Abaft the reservoir is a buoyancy chamber 14 inches long, permanently secured to the reservoir, and fitted at its after end with a water-tight bulkhead. Within this chamber is placed the diving gear, which regulates the depth below the surface at which the torpedo will travel, and which will be described further on. Through this compartment also passes the air pipe conducting air from the reservoir to the engine, which is located in the next compartment. This latter space is about 8 inches in length, and is in free communication with the water outside, through various openings in the shell. The admission of water to the engine compartment tends to prevent freezing of the engine, due to expansion of the air, avoids the difficulty of maintaining water-tight joints at the numerous openings necessary to give access to the mechanism, and serves another purpose, which will be explained in connection with the diving gear.

Back of the engine compartment, from which it is separated by a second water-tight bulkhead, is another buoyancy chamber, through which pass tubes for the propeller shaft and steering rod. Abaft of this compartment is the tail, the general construction of which may be seen from the cut, and which acts after the manner of feathers on an arrow, to keep the torpedo straight in its flight. The propeller wheels, as will be seen, are placed between the forward and after blades of the tail. These propellers are right and left hand; the after one being secured to the propeller shaft, and the forward one to a sleeve concentric with this shaft, and geared by four mitre wheels located in the forward part of the tail, to run in opposite direction to the other. The object of this arrangement is to balance the moment, which would tend to rotate the torpedo on its axis, if but one propeller were used.

The main engine consists of three cylinders grouped around the crank shaft 120 degrees apart, and cast in one piece with the crank



WHITEHEAD AUTOMOBILE TORPEDO.

Charge 120 lbs. of Gun-Cotton.
Total Weight 380 lbs.

Length 11 ft. 8 in.
Diameter 1 ft. 5.7 in.

Speed with initial air-pressure of 1350 lbs. per sq. in., over 800-yard course, 26 to 28 knots per hour.

Speed over 400-yard course, 31 knots.

case, valve chests and air passages. The cylinders are single acting, the connecting rods being jointed directly in the pistons, and the three working upon the same crank pin. The valves are of the piston type, and operated by a single cam on the crank shaft, against which they are kept in contact by the air pressure above them. The exhaust air passes into the crank case, and is thence conducted to the rear of the torpedo, by a passage drilled through the propeller shaft its entire length.

The controlling mechanism for the engine consists of a reducing valve, which may be set to operate the engine at any desired pressure; a starting lever, which is so connected with the reducing valve as to make it serve as a throttle valve as well: a "distance gear," by means of which, when the engine has made a prescribed number of revolutions, the valve will be closed, thus determining the distance the torpedo shall run; and a "retarding gear," which, when the starting lever is opened, as the torpedo leaves the launching tube, by contact with a latch placed in the tube, prevents the engine from racing while passing through the air.

The steering gear for directing the torpedo in a straight course horizontally consists merely of two small rudders, which can be adjusted by trial to counteract any tendency the torpedo may have to diverge from the straight path.

The gear for steering the torpedo to a set depth, and maintaining it at that depth, is somewhat difficult to explain without elaborate drawings. The general principle of its action, however, may be made clear. It should first be stated that the torpedo, when fully charged, has a slight surplus buoyancy, and is kept below the surface, entirely by the action of a horizontal rudder, so that when its headway is checked at the end of the run by the stoppage of the engine, it floats on the surface. This is, of course, necessary for its recovery in practicing. The rudder is controlled by a small steering engine (operated by compressed air), which is situated in the engine compartment. The valve of the steering engine is connected with a heavy pendulum, located in the diving compartment,

and so arranged, that when the pendulum hangs vertically, and the axis of the torpedo is horizontal, the rudder is held in a horizontal plane. When the position of the axis of the torpedo is changed 3 degrees, with the nose downward, the pendulum moves forward, and with it the valve of the steering engine; the rudder is thereby thrown up, tending to steer the torpedo back to the horizontal plane. The opposite action takes place when the nose is thrown upward. Thus, the action of the pendulum alone would keep the torpedo traveling in a horizontal plane, without regard to the depth of that plane below the surface. In the bulkhead dividing the engine compartment from the diving compartment is placed a movable diaphragm, which, being presented to the free water in the former compartment, receives a pressure therefrom due to the head of water above the torpedo. This pressure is counterbalanced by a spring within the diving compartment, which may be adjusted to balance any desired hydrostatic pressure upon the diaphragm, and which determines the "set depth." The movement of the diaphragm is so adjusted to the tension of the spring, that the diaphragm remains hard up against one limit of its travel, until the torpedo has descended to within 6 inches of the set depth, and moves to the other limit when 6 inches below that depth is passed. The valve of the steering engine, instead of being connected directly with the pendulum, is linked to one end of a lever, the center of which is linked to the pendulum, and the other end, which may be considered as the fulcrum, is linked to the diaphragm. When the diaphragm is at its central position, that is, when the torpedo is at its set depth, the action of the pendulum is as described above; and, as explained, it keeps the torpedo in a horizontal plane. If, however, the torpedo is above the set depth, the diaphragm has moved the fulcrum of the lever to such a position that, instead of the pendulum holding the rudder amidships when the torpedo is in a horizontal plane, it holds the rudder down until the torpedo is inclined downward at an angle of 3 degrees, at which point the rudder is brought to mid position; while, if the torpedo were to be inclined at a

greater angle, it would throw the rudder up, and bring her back to 3 degrees. If, on the other hand, the torpedo be below the set depth, the diaphragm, moving to the opposite end of its stroke, causes the rudder to assume the amidship position, when the torpedo is inclined 3 degrees upward. It will thus be seen that the torpedo is steered in a straight course, downward at 3 degrees with the horizon when above the set depth, parallel with the horizon when at the set depth, and upward 3 degrees when below the set depth. Therefore, when launched from above water, at whatever angle she happens to enter the water, she will at once be steered to 3 degrees downward until the set depth is reached, at which point her course will change to horizontal.

In the above explanation, it has been assumed that the pendulum will at all times hang in a vertical position. This, however, is not the case, and it is, therefore, necessary to provide additional mechanism.

The velocity acquired by discharge from the launching tube is much less than that attained subsequently. Therefore, during the period of acceleration, which takes place through about 50 or 60 yards, the pendulum, instead of hanging vertically, lags behind, and the downward angle at which the torpedo travels is increased beyond the 3 degrees by just the angle the pendulum hangs back from the vertical. The result is, that when the torpedo nears its set depth, it does not come to a horizontal course, but runs considerably below it, until acceleration ceases, when it comes to a horizontal course, and then upward to the set depth. This initial "dive" has a tendency to deflect it in its horizontal direction, especially in shallow water, where it may even strike bottom and be thrown entirely out of its course. To overcome this a locking gear is provided, which securely holds the valve of the steering engine at the center of its stroke, and therefore the rudder amidships, without regard to the pendulum and diaphragm, and which is automatically released when the engine has made a prescribed number of revolutions. This gear may also be adjusted, so as to change the locked

position of the rudder a trifle up or down, as experience may prove to give the best results.

The depth cards, Figs. 1 and 2, clearly show the effect of launching with and without locking. They are copies from actual shots, Fig. 1 being taken when the torpedo was launched without locking, showing the dive and recovery, and Fig. 2 when the gear

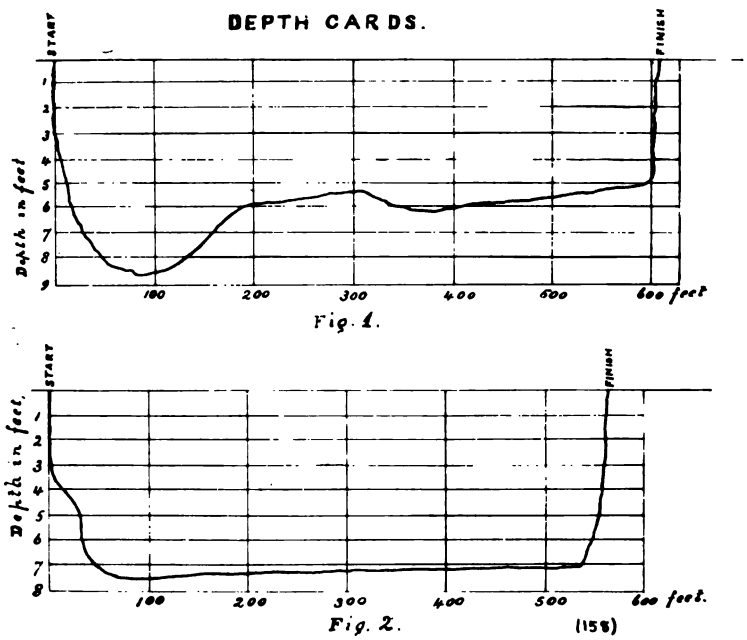


Fig. 1.

Fig. 2.

was locked. In this case, the rudder was locked slightly up, so that the torpedo was being steered in a circular path upward, which would soon have caused her to "broach," had not the gear unlocked and promptly changed the course, at the point where the sharp angle occurs. The cards are obtained by inserting in the nose of

the torpedo an instrument provided with a hydrostatic piston, which moves a pencil across the strip of paper, the latter being made to travel longitudinally by drums, geared to a small propeller wheel which is revolved by its passage through the water.

The speed of the torpedo, when fired at a range of 2,400 feet, is from 26 to 28 knots per hour; and, when the total available energy is used in a 1,200-foot run, 31 knots per hour can be maintained.

MECHANICAL AERATION OF WATER.

BY H. DE B. PARSONS, M. E., '84.

HAVING read with interest an article by Professor Albert R. Leeds, on this subject, in the last number of the INDICATOR, I take pleasure in offering the following experience which occured in my practice.

During the year 1888-89, I built the water-works for the city of Stevens Point, Wisconsin. The city contained about 10,000 inhabitants. The plant contained two 2,000,000-gallon compound-condensing direct-acting pumps, taking water from the Wisconsin River, through a 16-inch cast-iron suction. The pumps were connected with a Y-special, one branch being connected to the stand-pipe and the other to the distributing mains of the city. In consequence, when large quantities of water were being used by the city, the supply went direct from the pumps to the distributing mains.

A short time before the works were to be accepted by the city, I received many and well-founded complaints of the quality of the water, which had a bad smell, and was also discolored. I attributed it to the lowness of the river, and was greatly worried lest it might delay the acceptance of the works. At the time of the greatest

trouble, I noticed one day that the pumps were knocking more than usual, and discovered that the suction had an air leak. The engineer and the superintendent were very anxious to repair this at once, as they feared the City Council would think that the pumps were out of order. I, however, refused to do so, as I thought that the air might act beneficially on the water, although at that time I was unaware of Professor Leeds' experiments. I ordered some of the hydrants opened at the most distant points of the distributing mains, in order to allow the air to be carried through the pipes.

In a short time, I had many complaints about the "milky' appearance of the water, and was compelled to give a number of free lectures. In about two weeks, the river water greatly improved in quality, and I then closed the leak in the suction, and had no more complaints from the consumers.

During the time the air was being pumped into the mains, I did not discover that it located at the high points of the line. In order to satisfy myself, I opened many hydrants in all parts of the city; but from none of them did any volume of air come out before the water. The air seemed to be distributed in very small bubbles through the mass of water in the pipes. Occasionally I would find a little air in a rising pipe for house supply.

The average pressure on the mains was equivalent to a head of 120 feet.

THE HEATING OF LARGE BUILDINGS

BY ALFRED R. WOLFF, M. E., '76.*

THE large building of the present day, at least in America, must meet the needs and comforts of an intense, concentrated, nervous and busy "in-door" community—the product of our "rush" civilization. The very fact that both business and pleasures are indulged in on a large scale, in ceaseless haste and at high pitch, renders the community participating in them all the more sensitive to external discomforts, and unwilling to put up with any, not of their own individual creation. The very "crowding," and the physical strain and nervous excitement incident thereto, renders it important in the battle of existence, called "life," that the best conditions of health be artificially secured, so as to counteract, if possible, the individual natural neglect. But aside from this, and from a loftier point of view, the modern tendency is to demand the best attainable in every department of work. Whatever the reasons, the demand exists that the best conditions of health and comfort be secured in the large buildings, the meeting-places of the multitude. Thus there must be equable temperature, pure air, excellent light and fine sanitation, obtained artificially, almost irrespective of the control, crowding, physical and nervous state of

* A Lecture delivered before the Franklin Institute.

From advance sheets furnished by the *Journal of the Franklin Institute.*

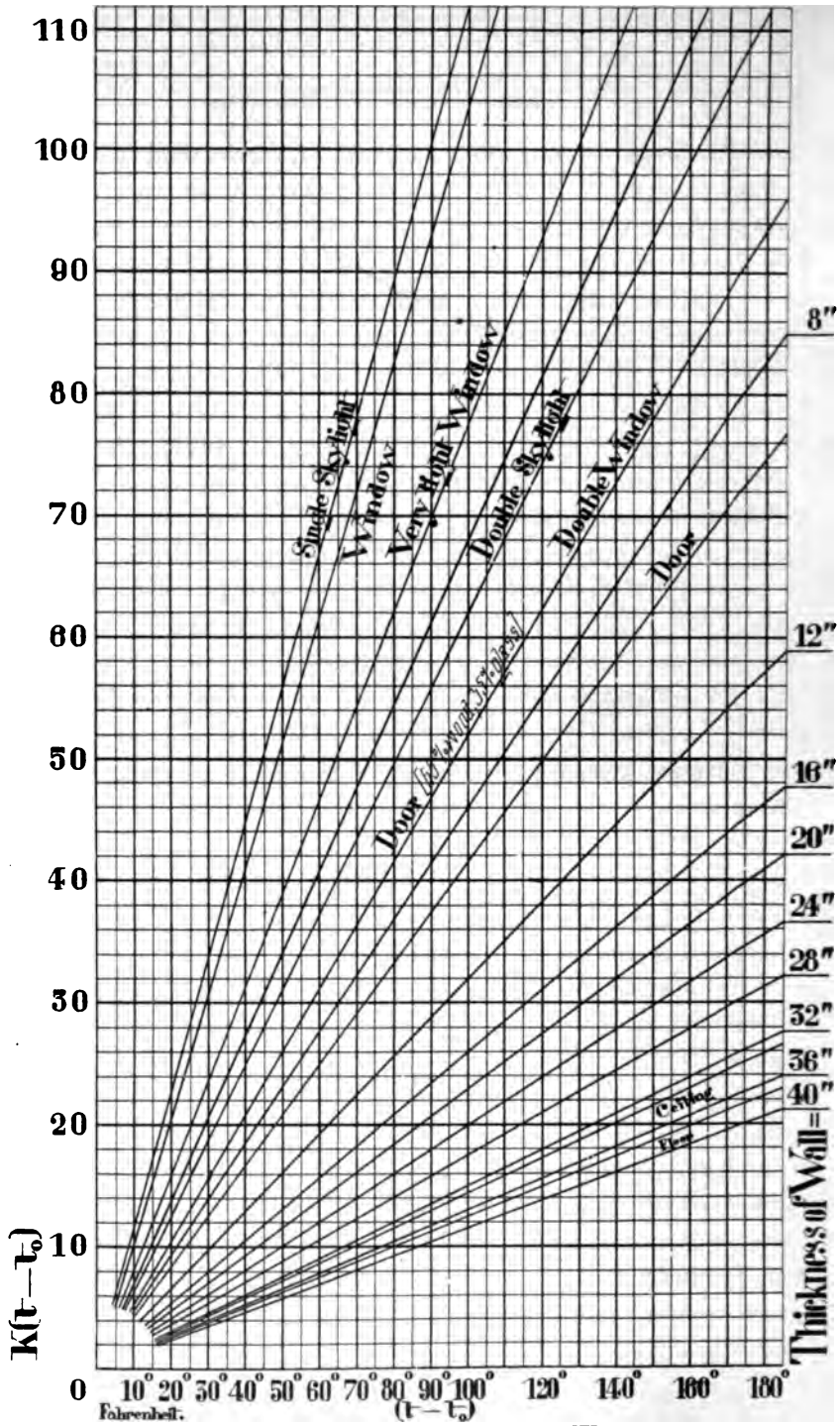
the inmates of the building, and irrespective of climatic and other conditions external to the building.

It is the solution of this problem which converts no small portion of the large modern building into a great factory for the generation and distribution of light, heat, cold, and currents of air and water. It is no longer unusual for our large hotels, office buildings and auditoriums, to contain a boiler plant of a thousand horse-power, with a corresponding electric lighting, heating, cooling and refrigerating system, nor for the equipment of these plants to require an outlay of hundreds of thousands of dollars. And, with these large machinery interests at stake, it becomes important that the skill of the trained engineer be called into play to ensure, in co-operation with the architect, the desirable and best attainable results, with a judicious expenditure of money.

During the past few years it has been my good fortune to have acted as consulting engineer in the design and erection of the engineering equipment of a number of large buildings, and, more particularly, of the heating and ventilating plants. On this account, doubtless, your otherwise astute committee has been deluded into the belief that a few words from me in relation to some of the principles and problems entering this specialty might be of passing interest; and if you thus become the innocent sufferers I, at least, am the gainer by having the pleasure of meeting you here this evening.

A systematic account of the various methods of heating in vogue, and their comparative merits, would, on account of the time-limits of our talk, necessarily savor too much of the elementary text-book; and would also, in all probability, convey but few facts not already known to you, or readily secured by perusing any standard work on the subject of heating and ventilation. So I have concluded to be real unsystematic, to make no attempt to be exhaustive, and only to relate at random a few points in connection with heating and ventilating large buildings, which have appeared of interest to me in my own practice.

I present, herewith, a diagram, showing, for different classes of surfaces composing buildings, co-efficients (K) of transmission of heat per hour for each square foot of surface for various Fahrenheit degrees differences between the temperature of the interior of a room and its external surroundings. This diagram is the graphical interpretation, in American units, of the practice and co-efficients prescribed by law by the German Government in the design of the heating plants of its public buildings, and generally used in Germany for all buildings. During the past six months, I have checked these co-efficients by examples of good American practice, and have found so satisfactory an agreement, that it has convinced me of the soundness of the German co-efficients, and their applicability to American practice; if, indeed, the well-known care and authority of publication of applied science under German Government patronage did not itself bespeak confidence. In the formula for total heat transmission, $Q = S\ K\ (t - t_0)$, K represents, for various materials composing buildings, the loss by transmission, in British thermal units per hour, for each degree of difference between the temperatures on the two sides of the material; S is the amount of transmitting surface, in square feet; t is the temperature in Fahrenheit degrees at the interior side, and t_0 the temperature in Fahrenheit degrees at the exterior side of the surface. The value of K varies, of course, not only with the class of surface, but also with its thickness. If, by means of the co-efficients given below, and summarized in multiples of temperature differences in the diagram, the loss by transmission of heat to the outside is calculated, we obtain the heat to be conveyed to the room in order to make good the loss due to transmission. This does not, of course, cover the additional heat to be conveyed on account of change of air for purposes of ventilation, but merely represents the loss due to heat transmission through walls, ceilings, windows, floors, etc., of buildings of ordinary good construction, with such slight accidental or natural ventilation as results from the porosity of the materials and construction.



Heat Transmitted, in British Thermal Units, per Square Foot of Surface, per Hour.

In detail, we have the co-efficient of transmission K as above defined, and as prescribed by the German Government (transformed into American units):

FOR EACH SQUARE FOOT OF BRICK WALL OF THICKNESS:

Thickness of brick wall=	4"	8"	12"	16"	20"	24"	28"	32"	36"	40"
K —	0.68	0.46	0.32	0.26	0.23	0.20	0.174	0.15	0.129	0.115

1 square foot, wooden beam construction, planked over, or ceiled: as flooring, K — 0.083; as ceiling, K — 0.104

1 square foot, fireproof construction, floored over: as flooring, K — 0.124; as ceiling, K — 0.145

1 square foot, single window ..... K — 0·776

1 square foot, single skylight ..... K — 1.118

1 square foot, double window ..... K — 0.518

1 square foot, double skylight ..... K — 0.621

1 square foot, door ..... K — 0.414

These co-efficients are to be increased respectively, as follows:

Ten per cent. where the exposure is a northerly one and winds are to be counted on as important factors.

Ten per cent. when the building is heated during the daytime only, and the location of the building is not an exposed one.

Thirty per cent. when the building is heated during the daytime only, and the location of the building is exposed.

Fifty per cent. when the building is heated during the winter months intermittently, with long intervals (say days or weeks) of non-heating.

The philosophy of these increases is, of course, apparent; for the co-efficients, as given, are for heat transmission alone, in usual everyday practice, where the temperature differences in the transmitting portions have assumed a fixed relation with a corresponding fixed rate of flow of heat. But, if the building gets chilled or entirely cold, through days or nights of disuse of heating system,

the exposed heat-transmitting portions must be first warmed to the staple degree referred to, which demands, for the time being, additional heat beyond the ordinary rate of supply if the period of warming up shall not be excessive. So, too, special cold winds beating on the exposed surfaces, form additional heat-abstracting media, beside increasing the amount of cold air entering the building through the pores of the materials, and through the ordinary cracks and crevices of well-constructed buildings.

In connection with calculations for heat transmission by means of the co-efficients here presented, the German Government prescribes that computations be made on the basis of the following assumed lowest temperatures:

External temperature		4° Fahr.
Assumed lowest temperature of non-heated cellar and other portions of building permanently non-heated		32° Fahr.
Vestibules, corridors, etc., non-heated, and at frequent intervals in direct contact with external air		23° Fahr.
Air spaces between roof and ceiling of rooms	Metal and slate roofs	14° Fahr.
	Denser methods of roofing, such as brick, concrete, etc.,	23° Fahr.

As the temperature to be attained in rooms of various kinds, the German Government prescribes for:

Stores and dwellings	68° Fahr.
Halls, auditoriums, etc	64° Fahr.
Corridors, staircase-halls, etc	54° Fahr.
Prisons, occupied day and night	64° Fahr.

It will be noted that these temperature stipulations vary from American practice in the following particulars:

1. Our calculations, in this vicinity, are based, in general, on an external temperature of 0° Fahr.

2. We figure on heating our corridors, staircase-halls, etc., to from 65° to 68° Fahr.

3. 70° Fahr. is the desired temperature in stores and dwellings, though 68° Fahr. appears to many of us pleasanter.

As a rule, Germans are disagreeably struck on their visits to this country, with the higher temperatures of our homes and offices.

Presently, a practical illustration of the method of using the co-efficients and diagram of heat transmission will be given; but, inasmuch as the same example can also serve the purposes of showing the method of determining the amount of air required for ventilation, and the amount of heat and of radiating surface to be provided to meet all conditions, it will be well to first call your attention to a few other facts in relation to heating and ventilation, which enter the problem.

The external air contains 4 parts of carbonic acid in 10,000, and a room is considered properly ventilated, when the proportion of carbonic acid present does not rise to above 6, possibly 8, parts in 10,000. It can readily be shown that to secure the standard of 6 parts in 10,000 means the addition of 3,000 cubic feet of fresh air per hour for each person in the room; to attain 7 parts the addition of 2,000 cubic feet; 8 parts, the addition of 1,500 cubic feet. This air may have to be heated, in the winter months, from zero degrees Fahrenheit to, say, 68° Fahr., and at times higher, if it is to be the means of taking care, in addition, of the heat transmission from the room.

Furthermore, it may be well to point out that the value of radiating surfaces is about as follows:

Ordinary bronzed cast-iron radiating surfaces, in American radiators (of Bundy or similar type), located in rooms, give out about 250 heat units per hour for each square foot of surface, with ordinary steam pressure, say 3 to 5 pounds per square inch; and about 0.6 this amount with ordinary hot-water heating.

Non-painted radiating surfaces, of the ordinary "indirect" type (Climax or pin surfaces), give out about 400 heat units per hour for each square foot of heating surface, with ordinary steam pressure, say 3 to 5 pounds per square inch; and about 0.6 this amount with ordinary hot-water heating.

A person gives out about 400 heat units per hour; an ordinary gas burner about 4,800 heat units per hour; an incandescent electric (16 candle-power) light about 1,600 heat units per hour.

Now, for the practical illustration: Let us consider, as per accompanying sketch, a large room used, say, as a lecture room, 40 feet by 60 feet and 20 feet high, situated as shown, and with exposures noted. Referring to our diagram, and to co-efficients of heat transmission, and to data named above, we obtain the following:

If we assume that the lecture room must be heated to 69° Fahr. in the day time, when unoccupied, so as to be at this temperature when first persons arrive, there will be required, ventilation not being considered, and bronzed direct low-pressure steam radiators in room being the heating media, about $\frac{113,550}{250}$ = about 455 square feet of radiating surface. (This gives a ratio of about 105 cubic feet of contents of room for each square foot of heating surface).

If we assume that there are 160 persons in the lecture room, and we provide 2,500 cubic feet of fresh air per person per hour, we will supply $160 \times 2,500 = 400,000$ cubic feet of air per hour—(*i. e.*, $\frac{400,000}{48,000}$ = over eight changes of contents of room per hour).

To heat this air from 0° Fahr. to 69° Fahr. will require $400,000 \times 0.0189 \times 69 = 521,640$ thermal units per hour (0.0189 being the product of a weight of a cubic foot by the specific heat of air). Accordingly, there must be provided $\frac{521,640}{400} = 1,304$ square feet of indirect surface, to heat the air required for ventilation, in zero weather. If the room were to be warmed entirely indirectly, that is, by the air supplied to room (including the heat to be conveyed to cover loss by transmission through walls, etc.,) there would have to be conveyed to the fresh-air supply $521,640 + 113,550 = 635,190$ heat units. This would imply the provision of an amount of indirect heating surface of the "Climax" type of

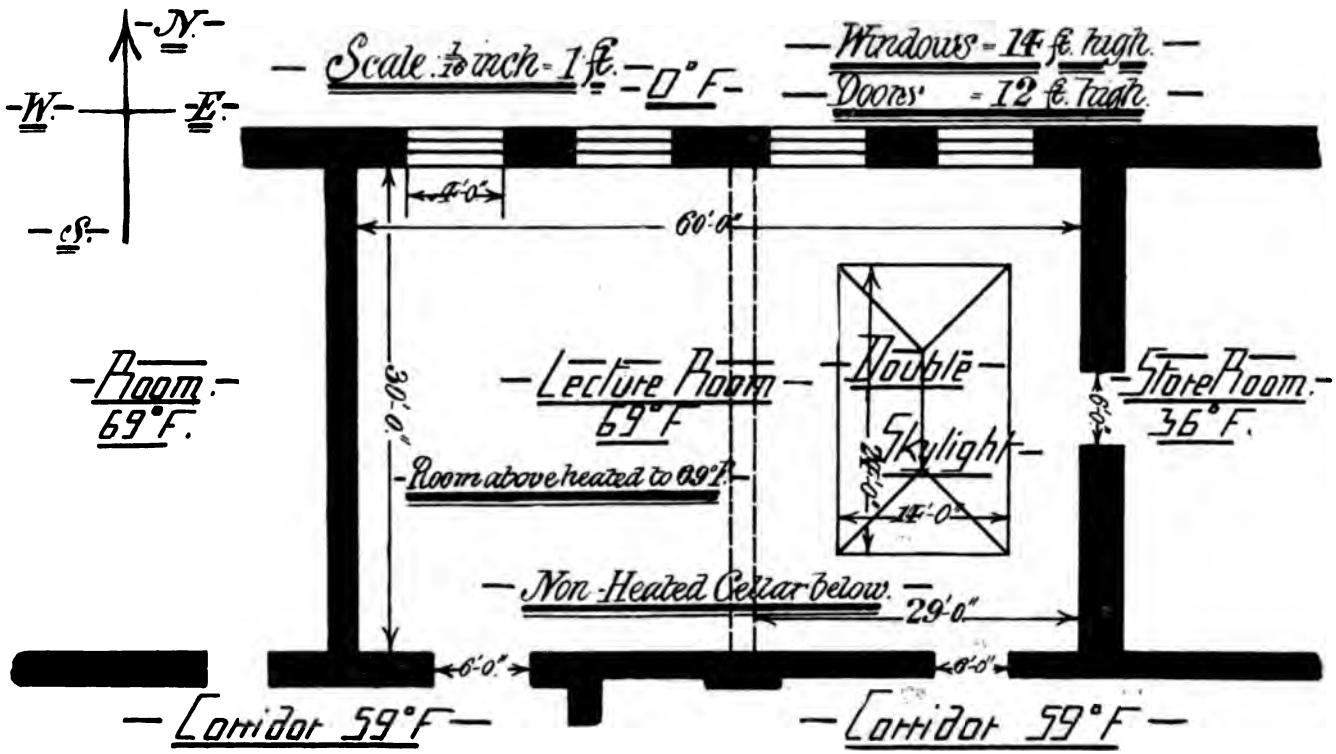

N.
W.
E.
S.
Scale. 1/16 inch = 1 ft.
0° F.
Windows - 14 ft. high.
Doors - 12 ft. high.
4'-0"
60'-0"
30'-0"
Room
69° F.
Lecture Room
69° F
Double
Skylight
14'-0"
24'-0"
Store Room
36° F.
6'-0"
Room above heated to 69° F.
Non-Heated Cellar below.
29'-0"
6'-0"
6'-0"
Corridor 59° F
Corridor 59° F

TABLE SHOWING HEAT UNITS TRANSMITTED FROM (AND TO BE CONVEYED TO) ROOM ON ACCOUNT OF HEAT TRANSMISSION THROUGH WALLS, CEILING, FLOOR, WINDOWS, ETC.

No.	Room.	Cubic Contents (in Cubic Feet).	t (Fahrenheit Degrees).	$t - t_0$ (Fahrenheit Degrees).	Kind of Transmitting Surface.	Thickness of Wall (in Inches).	Calculation of Area of Transmitting Surface.	Square Feet of Surface.	$K(t - t_0)$.	Thermal Units.	Supplementary Allowances.
	Lecture room	48,000	69	69	Outside wall.	36"	63 × 22 — 448	938	9	8,442	10 %
				69	Four windows (single).		4 × 8 × 14	448	72	32,256	10 %
				33	Inside wall (storeroom).	36"	42 × 22 — 72	852	4	3,408	
				33	Door.		6 × 12	72	19	1,368	
				10	Inside wall (corridor).	24"	45 × 22 — 72	918	2	1,836	
				10	Door.		6 × 12	72	5	360	
				10	Inside wall (corridor).	36"	17 × 22 — 72	302	1	302	
				10	Door.		6 × 12	72	5	360	
				69	Roof.		32 × 42 — 336	1,008	10	10,080	
				69	Double skylight.		14 × 24	336	43	14,448	
				33	Floor.		62 × 42	2,604	4	10,416	
										83,276	
							North outside wall,		10 %	844	
							North outside windows,		10 %	3,226	
										87,346	
							Exposed location and intermittent day or night use,		30 %,	26,204	
					Total					113,550	Thermal Units.

$\frac{635,190}{400} = 1,589$ square feet, and the fresh air entering the room would have to be at a temperature of about 84° Fahr.—viz., $69° + \frac{113,550}{400,000 \times 0.0189}$ or $69 + 15 = 84°$ Fahr.

The above calculations do not, however, take into account that 160 persons in the lecture hall give out $160 \times 400 = 64,000$ thermal units per hour; and that, say, 50 electric lights give out $50 \times 1,600 = 80,000$ thermal units per hour, or say, 50 gas lights, $50 \times 4,800 = 240,000$ thermal units per hour. The presence of 160 people and the gas lighting would diminish considerably the amount of heat required. Practically, it appears that the heat generated by the presence of 160 people, 64,000 heat units, and by 50 electric lights, 80,000 heat units, a total of 144,000 heat units, more than covers the amount of heat transmitted through walls, etc. Moreover, that if the 50 gas lights give out 240,000 thermal units per hour, the air supplied for ventilation must enter considerably below 69° Fahr., or the room will be heated to an unbearably high temperature. If 400,000 cubic feet of fresh air per hour are supplied, and 240,000 thermal units per hour generated by the gas must be abstracted, it means that the air must, under these conditions, enter $\frac{240,000}{400,000 \times .0189} =$ about 32° less than 84°, or at about 52° Fahr. Furthermore, the additional vitiation due to gas lighting would necessitate a much larger supply of fresh air than when the vitiation of the atmosphere by the people alone is considered, one gas light vitiating the air as much as five men. However, we need not consider these computations more in detail, our object being mainly to point out and illustrate the methods of analysis and calculation in such a case, and to show how readily the problems can be solved by the data herein given.

A few practical conclusions are at once apparent: That the amount of air required, and the temperature of the entering air, as well as the amount of heating surface to be called into play, will vary

very greatly in the same room, not only with variations in external temperature, but with any given external temperature, according to the use, occupation, method of lighting, etc., of the room. Also, that the variations will often be so quick during a short period of use of room, especially in auditoriums, theaters, ballrooms, public dining halls, etc., that it is important either to have automatic heat regulation, or a competent engineer, who constantly and closely watches the changes in temperature and modifies the operation of apparatus accordingly. Of course, a stable condition of audience, lighting, etc., once secured, the regulation is a comparatively simple matter (a fixed right condition of operation of apparatus then usually filling the need); but, from the time of opening the hall, until this stable condition is reached, conditions will vary so much, that failure is sure to result with the, otherwise, best apparatus, unless it be designed to regulate its heat radiation, etc., automatically, to suit these varying conditions, or a most competent engineer, of good judgment, regulate the apparatus, according to frequent thermo meter readings or reports.

From the considerations already set forth, and others to be presented, it will readily be inferred, that the almost general introduction of electric lighting with isolated generating plants in large buildings, has had a sensible effect on the solution of the heating and ventilating problem. On account of the economy secured, it has practically conditioned the use of exhaust steam for heating. It is an interesting fact that the quantity of steam required for heating and ventilating large buildings, notably club houses, colleges, theaters, halls, etc., equals closely the amount used independently for their electric lighting. Since electric light engines convert only about 10 to 15 per cent. of the heat of the steam with which they are supplied into mechanical energy, 85 to 90 per cent. of the heat is retained in the exhaust steam, available and just sufficient, as a rule, to meet the heating and ventilating needs of the building. This means, practically, that a boiler capacity ample for the heating and ventilating will

take care, in addition, of the electric lighting of a large building, or *vice versa;* and that, in the winter months, the electric lighting is secured at only a slightly increased fuel expense. It is this fact which makes it difficult for either city or district heating or electric lighting companies to supply steam or electricity, respectively, to large buildings. They cannot compete with the cheapness of generation of the composite system of electric lighting and exhaust steam heating of the isolated plant within the building. Of course, this composite system implies generally the additional wages of an extra fireman or engineer, but it can easily bear this additional expense, and still be decidedly on the winning side in competition with outside district companies. It is of importance to have the cylinder proportions of the electric light engines such that the desired power is developed with a back pressure as high as 5 pounds to the square inch; for, in American practice, such pressure may be required for heating in the coldest weather. This back pressure, if originally figured on, is neither detrimental nor uneconomical, and I have not been able to recognize any advantages in the vacuum systems, except where the engines or the piping were proportioned incorrectly at the outset, or where the installation of the electric lighting plant, and the use of exhaust steam for heating, were after-thoughts. In those cases, the vacuum systems frequently perform a useful service.

Another way in which the introduction of electric lighting has affected the heating and ventilating problem, is, as above already referred to, that the electric lights give out less heat and vitiate the atmosphere less than gas. Besides, there are no volatile products of combustion—representing vitiation and heat—to be taken off as far as practicable at the points of generation; nor must flicker of light, on account of air currents, be guarded against. The fact that a single gas light vitiates the air as much as do five persons, and that the electric light causes no vitiation whatever, materially affects the quantity of fresh air to be supplied, to keep the atmosphere within a room at a proper standard of purity. Again, the

fact that besides not dealing with obnoxious gases, no flicker of flames must be considered in electric lighting, renders it possible, when so desired, to bring in the fresh-air supply at the top of a room (either by wall registers or through perforated suspended ceilings) and to exhaust at the bottom, a reversal of the ordinary process, and one impracticable when gas lighting is resorted to.

While, in my judgment, the main problem in the proper ventilation of large buildings, is to secure an adequate supply to, and removal of air from, the separate rooms, I would like to call your attention to a distinct and important advantage obtained by having the air enter through perforated ceilings at the top of the rooms, and exhausting at the bottom. At night, in a crowded assembly, when the electric lights aglow are giving out some heat, even though it be considerably less than gas lights would evolve, it is frequently found in practice, as the calculations of our example have already indicated should be the case, that, even in very cold weather, to keep the air within the room at a temperature of 68° Fahr., the entering fresh air must be at a temperature considerably lower than 68 degrees. At the recent opening of the new concert hall of the Mendelssohn Glee Club Building, a room with scarcely any outside exposure, and practically dependent on an artificial air supply by means of a blower, it was found necessary, even while supplying over 3,000 cubic feet of fresh air per hour for each of the 1,000 persons in the audience, and with an external temperature of 40° Fahr., to have as low a temperature as 52° Fahr. for the entering air, to keep the hall at 68° Fahr. Nor is this an unusual experience.

If the entire air supply enters by means of registers, or openings in or near the floor, it is very difficult, however large the openings, to obtain such a distribution and low velocity, as will prevent the sensation of a cold draught, when air is entering in large volume at a low temperature. It is a possibility, but usually it is impracticable structurally, to secure the required low velocity and uniform distribution. But, if the air enters at the top, not only can a low velocity and uniform distribution be secured, by means of

large perforations in decorative designs of suspended ceilings, but a low velocity is of less importance, for the cooler air is heated in transit, and by the time it has reached the audience it has attained a temperature in the neighborhood of 68° Fahr., and is no longer cooler than the air at exhaust, where the people are congregated. If the hall is very high, it requires quite a powerful exhaust to ensure the air reaching the floor at such times as the entering air must be heated; but this is a detail readily solved in practice. In the main auditorium of the Carnegie Music Hall, with its seating capacity of over 3,000, the fresh, cooled or warmed air enters through perforations in the suspended ceiling, and travels with slow velocity a height of about 80 feet to exhaust openings in the floor risers, and an equable temperature is maintained under any external atmospheric conditions. In such a system, it is specially important that the volume of air exhausted be less than the volume of fresh (warmed) air forced into the hall, so that the air within the room be under pressure; otherwise, external cold air will be drawn into the building through doors and windows, and may create objectionable draughts. But the desired conditions here briefly presented are readily attainable; and, especially in case of an enclosed room, the system of supply at ceiling and exhaust at floor level is the ideal one, when the room is lighted electrically, to secure pure air and moderate temperatures, in crowded assemblies, during the winter months. In the summer time, many persons like to feel a decided current of cooled or cooler air; and thus it is often considered preferable to have the air enter at bottom and to exhaust at top of room. A reversible system may then be adopted to meet the conditions of comfort all year round.

In my own practice, when air enters and is exhausted through ducts in the walls, I have found it advantageous to have both top and bottom registers for each fresh-air flue, and top and bottom registers for each vent flue. In this way, the fresh air, when warmed, can enter at one and the same time through bottom and top register, with a corresponding desirable reduction in velocity,

each flue having two outlets. When the air, in the winter months, on account of crowded assembly, must enter at a low temperature, the bottom register can be closed, and in the summer time, if a current of cold air is to be strongly perceptible, the top register can be closed. In general, when air enters through top registers, the exhaust should also be by means of the bottom registers of the vent ducts, and *vice versa*, and when air enters through both top and bottom registers, the exhaust should also be through top and bottom registers.

The selection of the special system of heating and ventilating to adopt in a particular building depends, of course, in addition to the considerations already set forth, and to similar ones of a physical and engineering nature, greatly on the structural possibilities; for, important as are the heating and ventilation, owners and architects are not as yet quite ready to sacrifice other useful and artistic features to the one which has been the topic of this lecture. The engineer, therefore, if he would not have the heating and ventilating needs neglected, should be quick to recognize the system to adopt which will insure success, and will, at the same time, not prove a nuisance to the specific architectural and artistic interests of the building. Frequently, such decision must be cast at a first inspection of the plans. Of course, there should be "give and take" in this matter on both sides, and the purely decorative and structural interests should occasionally yield a point too.

It is evident that the best result is achieved if the engineer who is to design the engineering equipment be consulted when the original architectural plans are drawn, and before these plans have crystallized into definite and unalterable shape. For thus, in harmony of co-operation, the best is accomplished by both the architect and the engineer, and the engineering equipment, including the heating and ventilation, proves satisfactory, without encroaching on the highest architectural, structural and artistic possibilities and success. In closing, it is a pleasure to record that at the present time some of the leading architects recognize the advantages of an early co-operation in these respects with the engineer.

DEVELOPMENT OF THE SMOKE-BOX OF THE LOCOMOTIVE.

(CONTINUED.)

BY WM. A. FIELD, M. E., '91, AND JAS. T. WALLIS, M. E., '91.

HAVING thoroughly discussed the stack, attention is now turned to the working of the nozzle. At each exhaust a certain quantity of air is drawn through the fire-box; consequently, the difference of the pressure of the atmosphere and the pressure in the smoke-box must be large enough to overcome

1. The resistance offered the air by the ash-pan.
2. The resistance offered by the grate and fuel.
3. The friction of the air through the tubes of flues.
4. The resistance due to the contraction and expansion of the pipe system from the fire-box to the stack.

According to Zeuner, the weight per second of air $= L$.

$$L = D \sqrt{\frac{F_r^2 \left(\frac{F_s}{F_b} - 1\right)}{\mu F_s^2 + F_r^2}} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where D is the weight of steam per second.

F_b = area of nozzle; F_s = area of stack; F_r = total area of tubes.

$\mu = \frac{(1 + \alpha t_2)(1 + \varepsilon)}{2}$ in which t_2 = temperature of gases in the smoke-box:

α = co-efficient of expansion of the gases, and

ε = co-efficient of resistance to the air from the grate to the stack. μ is generally taken $= 4$, about.

This equation shows that, with a constant nozzle opening, constant position of the ash-pan damper, constant value for μ, the quantity of air is independent of the pressure of the blast, since the pressure of the blast is not contained in the formula. Further, it follows, that the quantity of air is directly proportional to the quan-

tity of exhaust steam—*i. e.*, if the engine gives out more tractive force, it exhausts more steam, and, consequently, draws in more air. Also

$$D = \frac{4\,y_o\,o}{\pi} \cdot \frac{s}{d}\, e \cdot v \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

o = area of piston.

$o = y_o$ density of steam in cylinder before expansion.

s = length of stroke in feet.

e = ratio of expansion.

v = velocity of locomotive.

d = diameter of piston rod.

Substituting this value of D in equation 1 gives

$$L = \frac{4\,y_o\,o}{\pi} \cdot \frac{s}{d} \cdot e\,v \sqrt{\frac{F_r^2 \left(\frac{F_s}{F_b} - 1\right)}{\mu\, F_s^2 + F_r^2}}.$$

It is seen from this equation that, with a constant nozzle opening, and constant position of the ash-pan damper, the quantity of air varies as the velocity of the locomotive, v, and the ratio of expansion, e, assuming a constant throttle position. Further, L is proportional to the density of the steam. Hence, if the throttle is wide open, the density increases correspondingly with the pressure, and the quantity of air also becomes greater.

According to Zeuner, a decrease, and correspondingly an increase, of 30 per cent. in the opening of the nozzle, produces an increase and decrease respectively of 21.7 per cent. and 23.9 per cent. in the quantity of air.

For variations in the value of μ (obtained from positions of the ash-pan damper), the following table gives the corresponding values for $\frac{L}{D}$:

μ —	3	6	9	12	15
$\frac{L}{D}$ —	2.3	1.883	1.634	1.462	1.336

If F = cross-section (area) of the nozzle in square meters, μ = average pressure of the blast in atmospheres, D = quantity of outflowing steam in kilogrammes per second. Then, according to Zeuner,

$$D = 287\ F\ \sqrt{\eta - 0.941}.$$

where the co-efficient of outflow is taken as 0.95.

Let η = the pressure of the blast above atmospheric in m.m. of mercury, then,

$$\eta = 0.009227\ \frac{D^2}{F^2}.$$

From this it is seen that the pressure of the blast above atmospheric varies directly as the square of the weight of outflowing steam, and inversely as the square of the nozzle area at the opening.

According to Welkner, the pressure of the blast = q,

$$q = \frac{p}{90} \cdot \frac{v}{1000} \left\{ \frac{v}{100} \cdot \frac{\mu}{8} \cdot \frac{a}{6} \right\}$$ pounds per square inch, where

p = boiler pressure in pounds per square inch.

v = velocity of piston in feet per minute.

η = ratio of area of piston to area of blast nozzle.

a = degree of expansion of the steam in the cylinder, measured in percentage of stroke.

The vacuum in the smoke-box is (from Zeuner)

$$\frac{u}{\eta} = 2 \cdot \frac{\mu}{\alpha} \left(\frac{F_b}{F_r}\right)^2 \cdot \left(\frac{L}{D}\right)^2;$$

where u = pressure of atmosphere above that in the smoke-box.

η = the pressure of the blast above the atmosphere.

α = 1.25; the other quantities having the same designation as before.

From Mr. Clark's investigations, in good locomotives:

1. The vacuum in the smoke-box is about one-fourteenth the blast pressure.

2. The vacuum in the fire-box is nearly one-half that in the smoke-box, or one-twenty-eighth the blast pressure.

3. The briskness of combustion, measured by the quantity of water evaporated in equal times, increases nearly proportional to the square root of the vacuum in the smoke-box: so that quadrupling the vacuum in the smoke-box doubles the rate of evaporation.

EXPERIMENTS ON ENGINE NO. 760.

To enable the writers to determine how far these theoretical deductions are borne out in practice, by actual results, experiments were made on a standard class "O" engine, on the P. R. R., the dimensions of which are substantially as follows:

Length of boiler 23 feet 7 inches.	Length of fire-box (inside) 6 feet ⅜ inch.
Diameter of boiler 57 inches.	Width of fire-box (inside) 34½ inches.
Length of tubes 11 feet 5 inches.	Length of smoke-box (inside) 65¾ inches.
Number of tubes 196.	Length of stroke 24 inches.
Diameter of tubes 1¾ inches.	Boiler pressure (pounds per sq. in.) 160.
Diameter of cylinder 18 inches.	Drive wheels (diameter) 62 inches.

Total flue area (cross-section) 471.42 square inches.

Locomotives of this type were put in service during the past year; and it was evident, from their performance with a double nozzle, which would enable them to be reasonably free from back pressure, that they would not steam with sufficient freedom.

As a preliminary step, an engine of this type, No. 1397, on a level division, was equipped with a short stack, made to conform approximately to the theoretical stack, and with a single nozzle 4¾ inches in diameter, as shown in Fig. 13. The area of the orifice corresponding to this diameter is 17.72 square inches, while the area at the termination of the double passage was 17.92 square inches for each passage.

The performance of this engine showed that there was little, if any, back pressure; but, while its performance was satisfactory on average runs, it would not steam sufficiently well with an increase of train load or speed.

To determine how well an engine of the same type, similarly equipped, would steam in very heavy service, on the eastern slope of the mountain division having an average grade of 95 feet to the mile, several trips were made. The steaming of the engine was wholly insufficient for the performance of the work. A reduction of the size of the nozzle on this engine to improve the steaming, while it accomplished what was desired, resulted in back pressure sufficient to cripple the engine considerably.

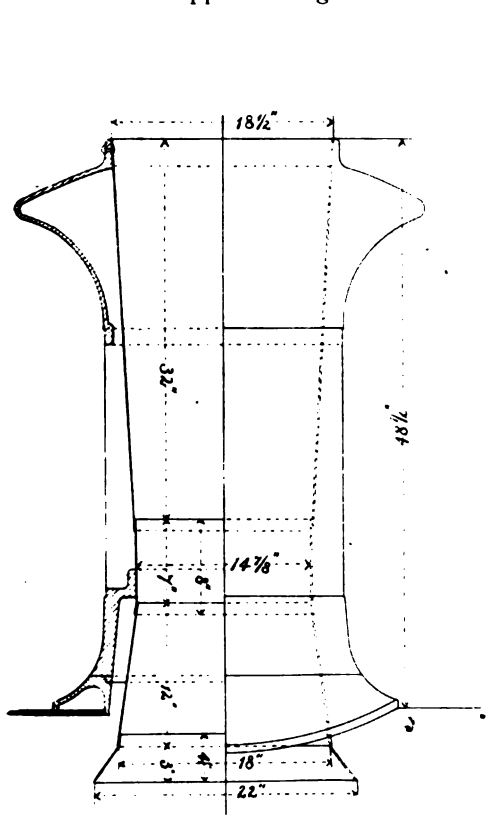


FIG. 13.

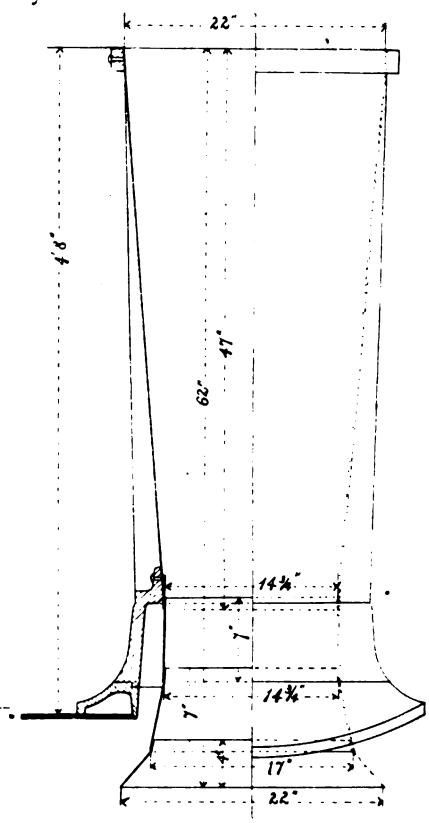
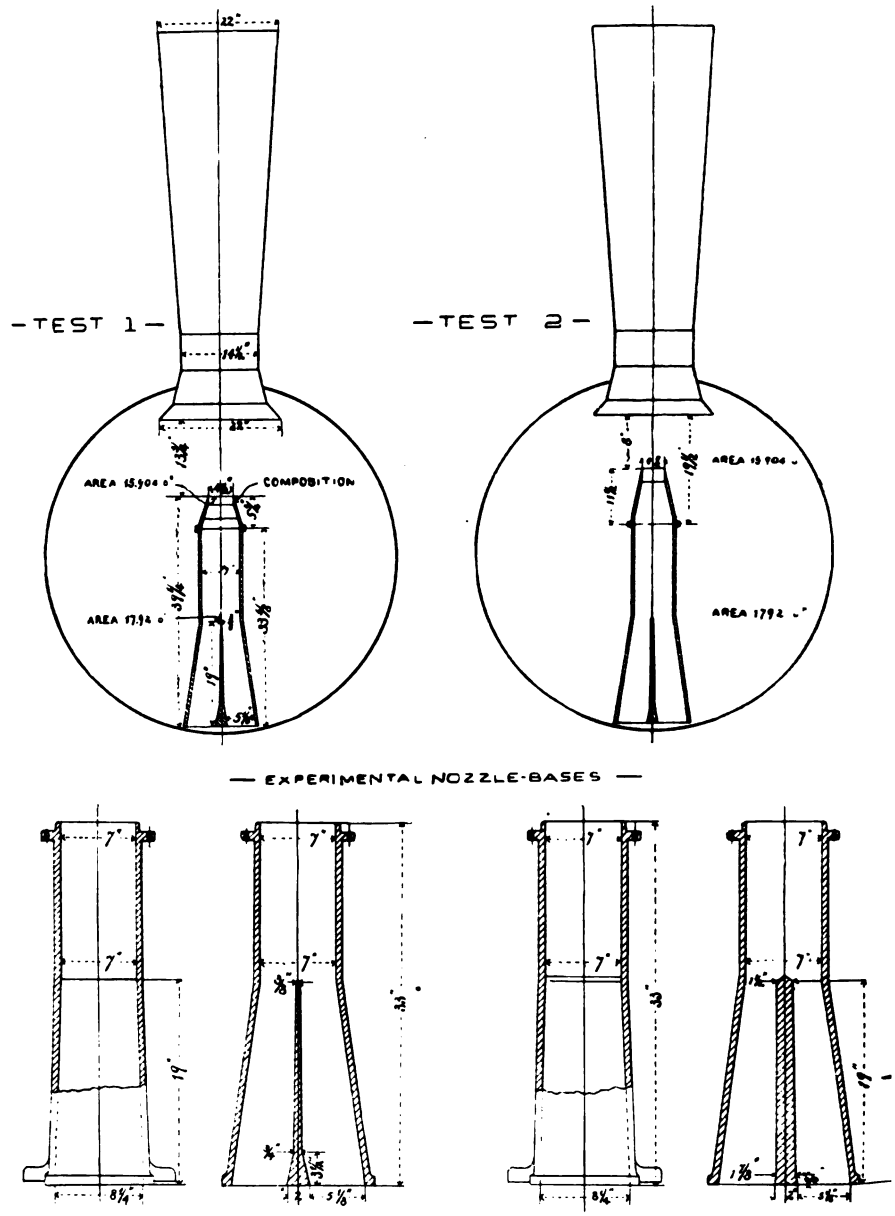


FIG. 14.

To ascertain whether the performance of the engine on the mountain division could be varied by the design of the stack, the short one was removed, and one made more nearly in accordance with theoretical considerations was substituted. It is shown in Fig. 14.

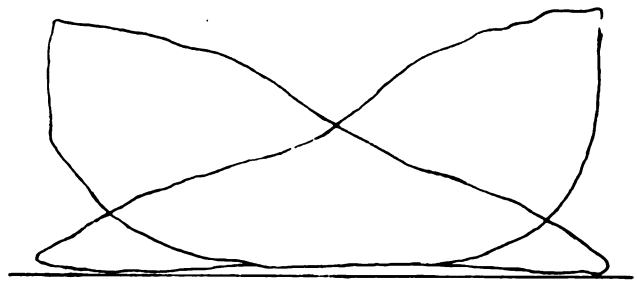

— TEST 1 —
— TEST 2 —
AREA 15.904 □"
COMPOSITION
AREA 17.34 □"
AREA 15.904 □"
AREA 17.92 □"
— EXPERIMENTAL NOZZLE-BASES —

Test 1 shows both the dimensions of the stack, the shape of the nozzle, and their relation to each other. It will be seen that the

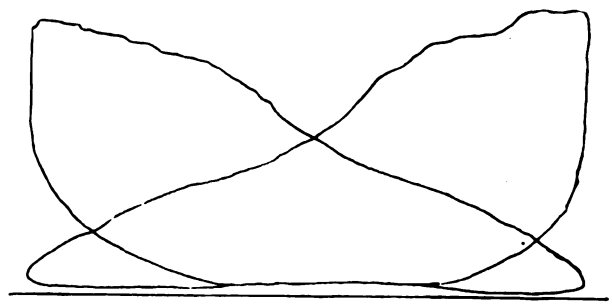
TEST 1.

SPRING 100.

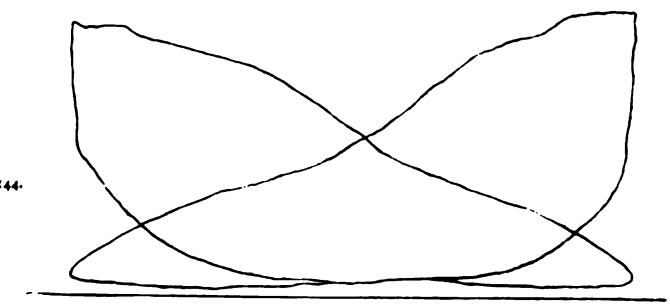
Best
Card No. 3.
Rev. per min., 120.



Average
Card No. 4.
Rev. per min., 124.



Worst
Card No. 7.
Rev. per min., 144.



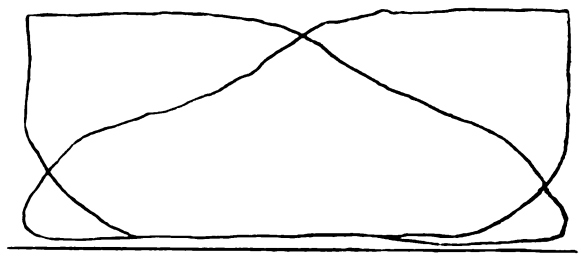
orifice is 4½ inches in diameter, corresponding to an area of 15.9 square inches; while the area of the bridge is 17.92 square inches. The indicator cards taken with this arrangement, show the hump in

the back pressure, previously referred to; clearly establishing the fact, that, where the area at the top of the bridge is greater than the area at the tip, the free exit of the steam from the opposite cylinder is obstructed, and the hump is the result.

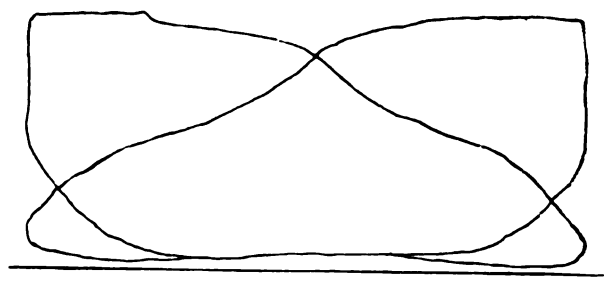
TEST 2.

SPRING 100.

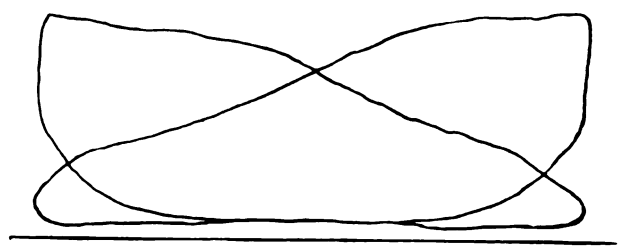
Best
Card No. 9.
Rev. per min., 136.



Average
Card No. 7.
Rev. per min., 155.



Worst
Card No. 10.
Rev. per min., 162.



The steam pressures, as will be observed, are fairly uniform. In the tables on pages 43, 44, 45 and 46, the positions of the reverse lever notch are given, as well as the vacuum in the smoke-box.

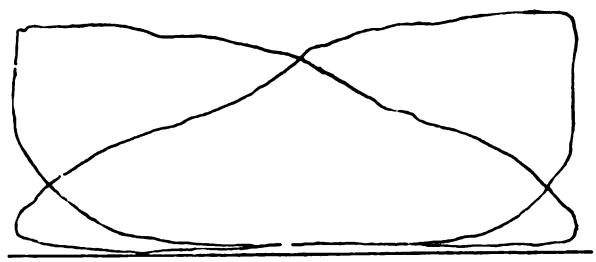
In Test No. 2, the arrangement remained entirely the same, except that the distance between the nozzle tip and the base of

the stack had been reduced from 15 inches to 8 inches. The cards show little, if any, improvement in back-pressure; but the vacuum in the smoke-box is considerably lower. This was to be expected, because the jet of steam issued from the nozzle at too great a height to allow the stack to be properly filled with steam and gases.

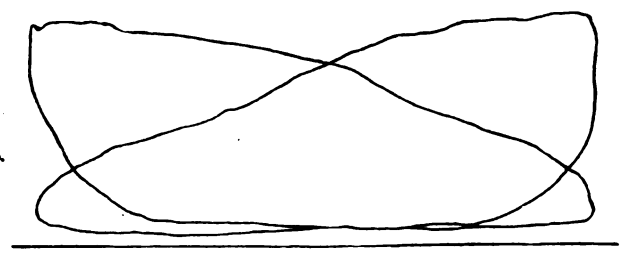
TEST 3.

SPRING 100.

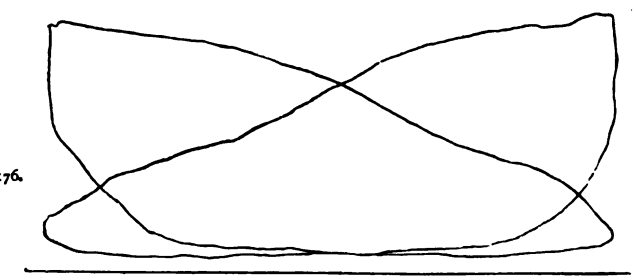
Best
Card No. 9.
Rev. per min., 124.



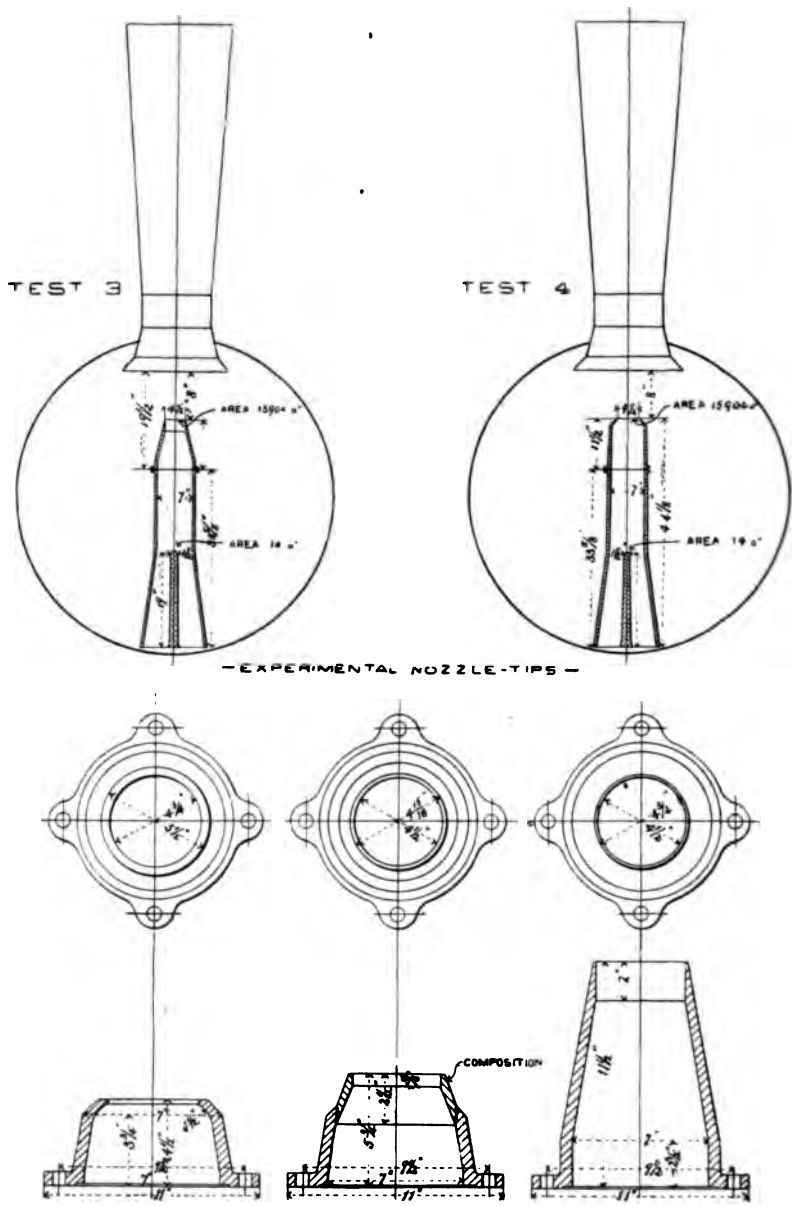
Average
Card No. 8.
Rev. per min., 160.

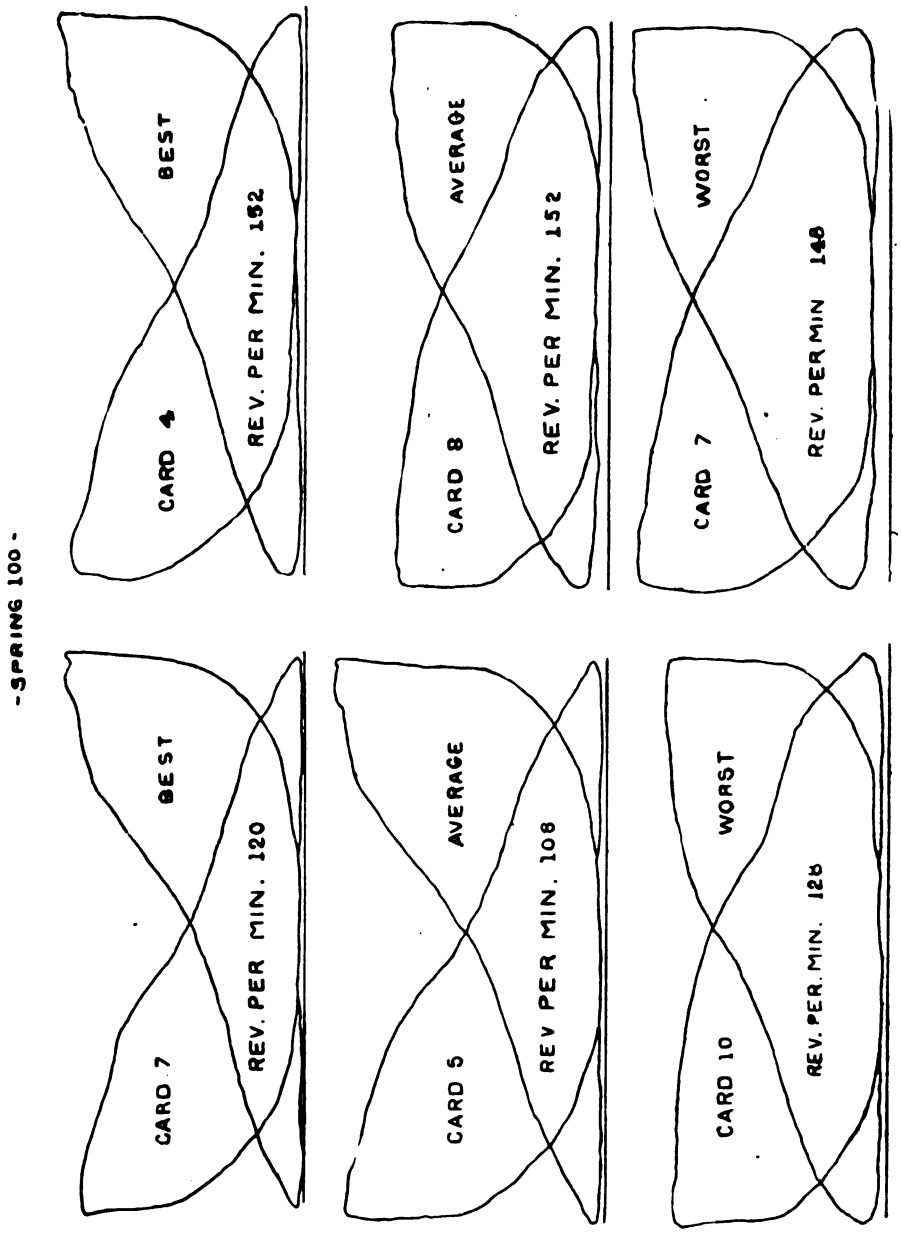


Worst
Card No. 5.
Rev. per min., 176.



In Test No. 3 the conditions remained the same as in No. 2, except that the area of the bridge was reduced from 17.92 square inches to 14 square inches; or, in other words, the area at the bridge was less than the area at the tip. The cards here show a marked


TEST 3
TEST 4
AREA 19 0"
AREA 19 0"
— EXPERIMENTAL NOZZLE-TIPS —
COMPOSITION


-SPRING 100-
CARD 7
BEST
REV. PER MIN. 120
CARD 4
BEST
REV. PER MIN. 152
CARD 5
AVERAGE
REV PER MIN. 108
CARD 8
AVERAGE
REV. PER MIN. 152
CARD 10
WORST
REV. PER. MIN. 128
CARD 7
WORST
REV. PER MIN 148

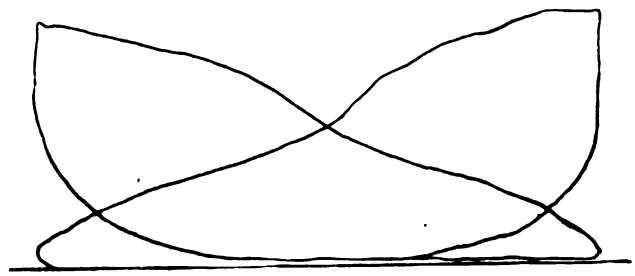
improvement, the hump being almost entirely gone, the steam pressure about the same as before, but vacuum slightly increased.

Test No. 4 was made under the same conditions as No. 3, except a modification in the form of the nozzle tip. In the three first

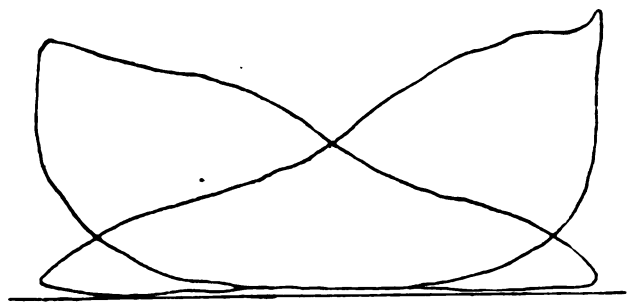
TEST 5.

SPRING 100.

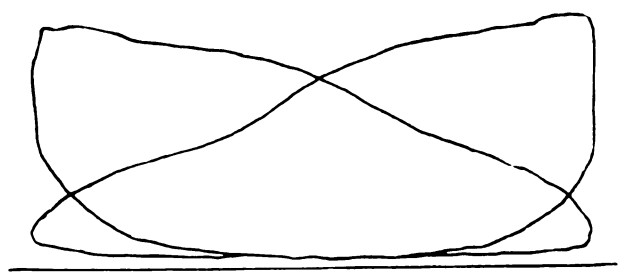
Best
Card No. 4.
Rev. per min., 136.



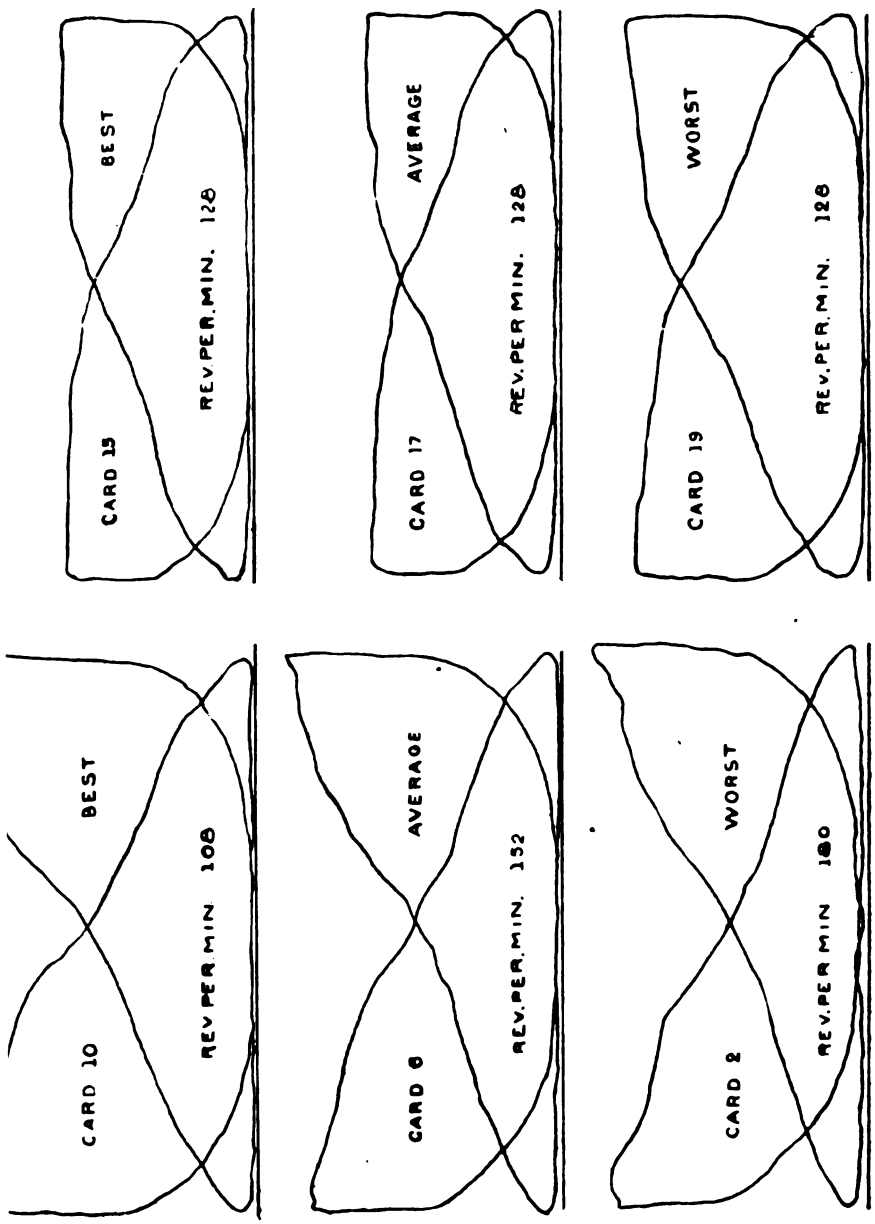
Average
Card No. 7.
Rev. per min., 156.

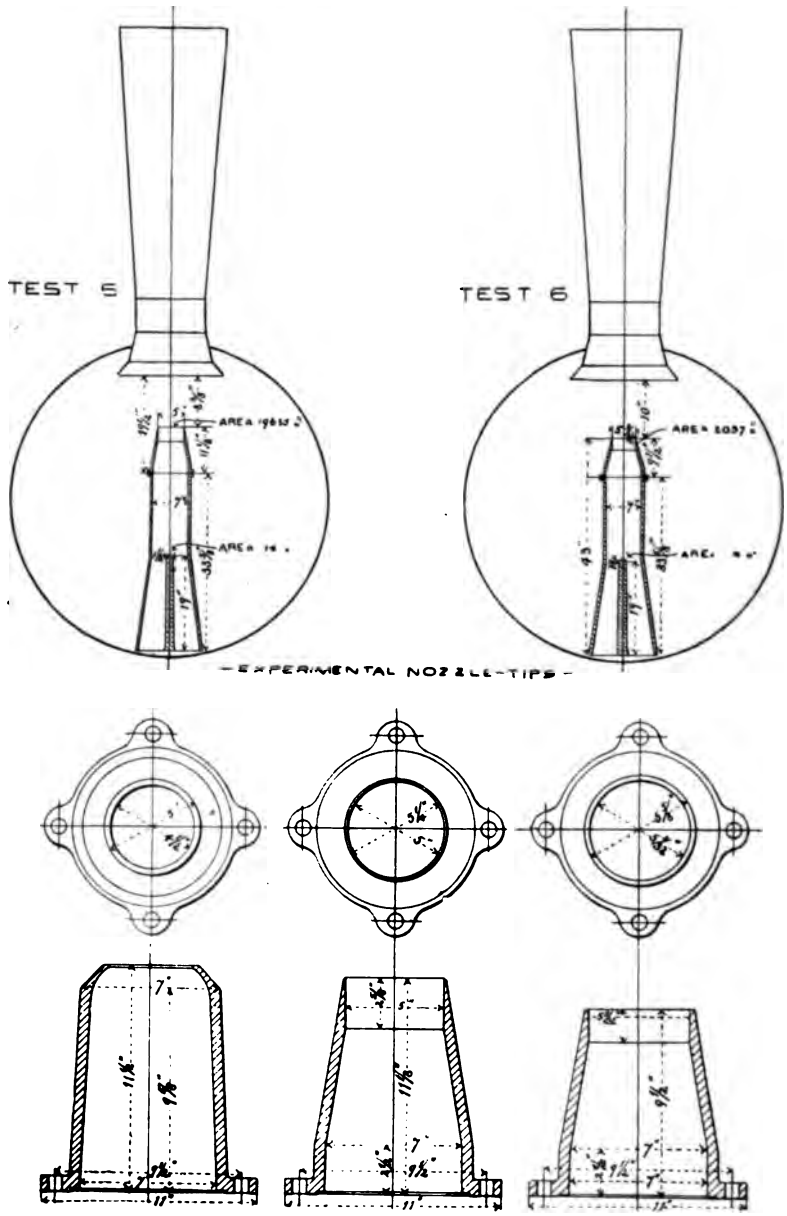


Worst
Card No. 2.
Rev. per min., 160.



experiments the exit passage of the tip was cylindrical for a distance of one-half the diameter, the sides gradually sloping to it. In No. 4, however, the orifice was formed by a rather sudden contraction at


BEST
CARD 15
REV.PER.MIN. 128
AVERAGE
CARD 17
REV.PER.MIN. 128
WORST
CARD 19
REV.PER.MIN. 128
BEST
CARD 10
REV.PER.MIN 108
AVERAGE
CARD 6
REV.PER.MIN. 132
WORST
CARD 2
REV.PER.MIN 180


TEST 5
TEST 6
EXPERIMENTAL NOZZLE-TIPS

the tip, the sides below being nearly parallel. This arrangement showed a still further improvement in the cards, the back pressure more nearly coinciding with the atmosphere, the steam pressure being quite satisfactory, and the vacuum slightly less.

In Test No. 5 the nozzle was bored out to 5 inches in diameter, the distance between the tip of the nozzle and base of the stack remaining practically the same. The area at the bridge was 14 square inches for one passage, while that at the tip was 19.5 square inches. An entire elimination of the hump would be expected from the freedom with which the steam would pass out of the tip after leaving the bridge. The boiler pressures show very satisfactory steaming results, with slight improvement in vacuum, due to the fact that the exhaust steam issued from a larger opening and more effectually filled the stack.

A still further enlargement was made in Test No. 6, also increasing the distance between the tip and base to 10 inches. A careful examination of the cards will show as fair a performance as can be expected in locomotive practice, as far as both hump and back pressure are concerned. The steam pressures are comparatively high, and the vacuum is slightly improved over the last test.

This is decidedly the best arrangement so far, and approaches nearer to theory than any of the previous tests.

On pages 32, 36 and 40 are shown the experimental bases and nozzle-tips used in the tests.

The points yet to be satisfactorily determined by theory are:

1. The relation of the vacuum in the smoke-box to the steaming qualities of the engine. It would seem that a certain vacuum much lower than is usually thought necessary would suffice to produce good steaming qualities, and all in excess of this would result in drawing unconsumed fuel through the tubes.

2. With a proper vacuum, what cubic capacity of the smoke-box is necessary to produce the best results?

The experiments of D. K. Clark go to show that the smallest smoke-box, within certain limits, will give the best results. How far the theoretical arrangement of nozzle and stack will result in drawing through the tubes the least amount of unconsumed fuel, is yet an open question. The blast may be so mild that it will be impossible to exhaust from the stack even very fine particles. If this is the case, they will rapidly accumulate, and frequent stops may be required to remove them, or the cubic capacity of the smoke-box will have to be reduced, to such an extent, that they will be thrown out.

The condition in which these particles reach the smoke-box will determine whether they can be allowed to go out, or not. If in a highly incandescent, state they must be retained, and the smoke-box must then be so proportioned that they will remain in it until they become extinguished.

It is unfortunate that, at the present time, experiments on the Pennsylvania Railroad have not reached a conclusion. The writers hope, however, to submit a supplementary paper in the near future, giving final determinations, not only for passenger, but for freight service as well. The results so far obtained lead to the following conclusions:

1. That theoretical results *can* be obtained in practice.

2. On railroads with moderate grades theoretical considerations will be found in practice with little or no variation, while on those with heavy grades variations will exist.

3. These variations from theory will be confined mainly to the area of the exhaust orifice.

4. The theoretical conditions of the chimney will always be found to exist in practice.

5. That any variation from the theoretical area of the exhaust orifice, due to variation in work demanded, will be accompanied by a variation in the distance between the tip of the nozzle and the throat of the stack.

On this depends absolutely the steaming qualities of the engine, in other words, the vacuum in the smoke-box.

TEST NO. 1. ENGINE NO. 760. MAY 7, 1891.

Number of Card.	Time. Leaving A. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure Lbs. per Sq. In.	Vacuum in Inches of Water.
....	8.52	Altoona.	....	....	....	152	...
1	...	B O	154	8	9	154	6½
2	9.04	....	152	8	9	152	6
3	...	...	120	8	9	147	5¼
4	9.07	....	124	8	9	150	5½
....	....	.. .	...	8	9	...	1–5 2–5 3–5
5	9.11	K N	126	8	9	146	5
6	9.15	I A	132	8	9	158	6
7	9.17½	....	144	8	9	153	5½
8	. . .	A G	146	7	10	144	6¼
9	9.23	Bennington	140	7	10	135	6
....	....	....	....	7	10	130	1–6 2–6 3–6
10	9.24	S F	132 (?)	7	10	126	6

TEST NO. 2. ENGINE NO. 760. MAY 7, 1891.

Number of Card.	Time. Leaving P. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure. Lbs. per Sq. In.	Vacuum in Inches of Water.
....	3.55	Altoona.	....	....	....	160	....
1	....	J K	148	8	8	139	4½
2	....	B O	158	8	8	157	4¾
3 (?)	4.03	....	....	8	8	152	4½
4	4.03½	G Y	148	8	8	149	4¼
5	....	....	136	8	8	142	4
....	4.09	....	....	....	....	143	1–3¾ 2–3¾ 3–3¾
6	4.13	I A	144	7	8	149	6
7	....	....	144	7	9	148	5¾
8	...	....	192	7	9	145	6
....	4.18	A G	....	....	....	142	...
9	....	....	136	7	9	140	5½
10	4.21	....	152	7	9	140	6
11	4.25	....	....	7	9	137	5½

TEST NO. 3. ENGINE NO. 760. MAY 9, 1891.

No. of Card.	Time. Leaving P. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure Lbs. per Sq. In.	Vacuum in Inches of Water.
...	3.52	Altoona,	...	....	....	157	....
1	...	....	168	7	9	156	5
2	....	....	164	7	9	147	5½
3	....	....	160	7	9	146	7
...	4.00	G Y	....	7	9	143	...
4	....	....	168	7	9	144	6½
5	....	...	176	7	9	152	7
....	4.05	K N	....	6	10	....	1–7 2–7 3–7
6	....	....	132 (?)	7	10	155	6
7	....	....	160	7	11	142	7
8	4.14	I A	160	7	11	130	5
9	....	A G	124	7	11	130	5
10	....	...	152	7	11	131	6
11	....	....	150	6	12	137	7
....	4.22½	S F	....	....	....	137	1–6½ 2–6½ 3–9½

TEST NO. 4 A. ENGINE NO. 760. MAY 11, 1891.

Number of Card.	Time. Leaving A. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure Lbs. per Sq. In.	Vacuum in Inches of Water.
....	8.18	Altoona.	....	....	....	170	....
1	....	....	120	8	8	169	3
2	....	....	148	8	8	164	4
3	....	....	108	8	9	157	3½
4	8.27	G Y	100	8	9	154	3
5	....	...	108	8	9	156	3
6	....	.. .	120	8	9	149	2½
....	8.34	K N	120	8	9	138	1–2 2–2½ 3–2
7	....	....	120	8	9	139	2½
8	....	....	132	8	9	152	3
9	....	...	128	8	9	151	3
10	8.41	A G	128	7	9	146	3½
11	....	....	124	7	9	136	4
12	...	....	140	7	9	129	3
....	8.48	S F	....	....	....	125	1–2½ 2–2½ 3–3

TEST No. 4 B. ENGINE No. 760. MAY 12, 1891.

Number of Card.	Time. P. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch	Boiler Pressure Lbs. per Sq. In.	Vacuum in Inches of Water.
....	3.45	Altoona.	....	....	. ..	140	4
1	....	....	156	8	8	160	4
2	....	....	146	8	9	155	4
....	3.54	G Y	....	...	....	...	....
3	...	....	160	8	9	152	4
4	....	....	152	8	9	150	....
...	4.00	K N	....	....	....	...	1–3½ 2–4 3–4
5	...	....	144	7	9	158	4½
6	....	....	136	7	12	152	4½
7	....	....	148	7	12	150	5
....	4.09	A G	....	....	12	....	....
8	....	....	128	7	12	140	4
9	....	..	152	7	12	131	4
10	....	....	124 (?	7	12	135	3
....	4.12	S F	....	....	....	...	1–3 2–3½ 3–4

TEST No. 5. ENGINE No. 760 MAY 13, 1892.

Number of Card.	Time. P. M.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure. Lbs. per Sq. In.	Vacuum in Inches of Water.
....	3.48	Altoona.	....	....	....	160	....
1	....	....	160	7	9	155	4
2	....	....	160	8	12	150	4
....	3.55½	G Y	....	8	12	150	.. .
3	....	....	144	8	12	149	4
4	....	....	136	8	12	145	3½
...	4.01	K N	....	....	..	147	...
5	...	....	136	7	12	140	4
6 (?)	4.05	I A	....	....	12	145	...
7	....	....	156	8	12	156	4
...	4.10½	A G	....	.	...	150	...
8	....	....	112	8	12	150	4½
9	...	...	164	7	11	140	4½
10	....	....	90	7	12	140	4
....	...	S F	...	7	....	142	....

TEST No. 6. ENGINE No. 760. MAY 14, 1891.

Number of Card.	Time.	Place.	Rev. per Minute.	Reverse Lever Notch.	Throttle Lever Notch.	Boiler Pressure Lbs. per Sq. In.	
	P. M.						
...	3.48	Altoona.	...	....	....	160	...
1	....	....	156	8	9	158	4
2	....	....	180	8	12	155	5
3	....	....	168	8	12	152	4½
4	....	....	144	8	12	153	4½
....	3.56	G Y	....	. ..	12	154	...
5	....	....	148	8	12	154	4
6	....	....	152	8	12	153	4
7	....	...	148	8	12	150	4
8	....	....	140	8	12	145	4
...	4.01	K N	....	....	....	145	1–3½ 2–4 3–3½
9	...	....	132	7	11	137	4½
. ..	4.05½	I A	....	....	....	135	....
10	....	....	108	8	11	151	3
11	....	....	144	8	11	155	4
12	...	....	136	8	11	151	3
13	...	....	132	8	11	148	4
....	4.11½	A G	..	....	....	145	....
14	....	....	108	7	9	147	4
15	...	...	128	7	9	142	4
16	....	....	128	7	9	138	4
17	....	..	128	7	9	133	4½
..	4.17	Bennington.	....	....	....	135	....
18	....	....	92	7	12	141	3½
19	....	....	128	7	12	140	4½
...	4.20	S F	....	7	12	140	1–4 2–4 3–4
....	4.22	U N	....	...	....	130	....

A NEW RECORDING PRESSURE GAUGE FOR EXTREMELY LOW RANGES OF PRESSURE.

BY PROF. W. H. BRISTOL.*

SINCE describing and exhibiting a sinuous tube recording pressure gauge† at the New York meeting of the Society in November, 1889, many of the instruments have been placed in successful operation; but it has been found impracticable to make guages on the flattened sinuous tube principle which would be sufficiently sensitive to register extremely low ranges or variations of pressure. Such are the variations due to a difference of $\frac{1}{10}$-inch head of

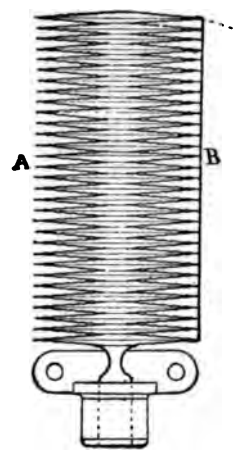


FIG. 1.

water, as in the case of illuminating gas in street mains, where the total range rarely exceeds two ounces per square inch, or its equivalent, 4 inches head of water. For such extremely low pressure, it

*Presented at the New York meeting (November, 1892,) of the American Society of Mechanical Engineers; also the discussion which the paper received.

†Transactions A. S. M. E., Vol. XI., p. 225, No. 368.

was necessary to offer a very large area for it to act against. This has been accomplished by employing a series of corrugated diaphragms A placed as shown in cross-section in Fig. 1. The diaphragms are arranged in pairs and joined, as shown, with a continuous opening through the line of centers of the different pairs, thus permitting the pressure to exert itself simultaneously on the

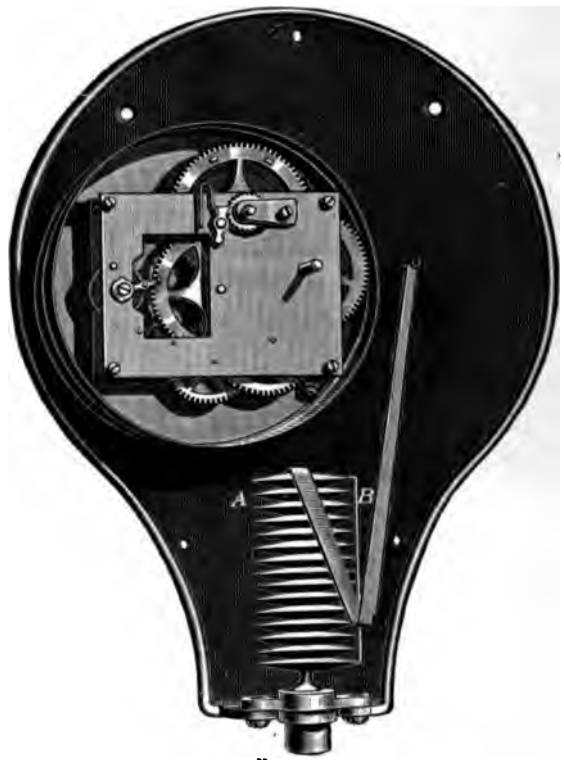


FIG. 2.

interior of every pair, the effect of variations being to produce an elongation of the whole.

This arrangement of diaphragms is employed in the construction of certain self-registering barometers, the small motion of the diaphragms being made available by a train of multiplying mechanism. In the guage now exhibited, the disadvantage of using multiplying devices is entirely obviated by simply securing a flexible strip B

along the edges of the diaphragm tube, as it might be called. The effect of applying the flexible strip is two-fold : first, it stiffens the diaphragm tube as a whole ; and second, it performs the most important function of resisting the tendency of the pressure to elongate it, which naturally results in producing a greatly multiplied lateral motion.

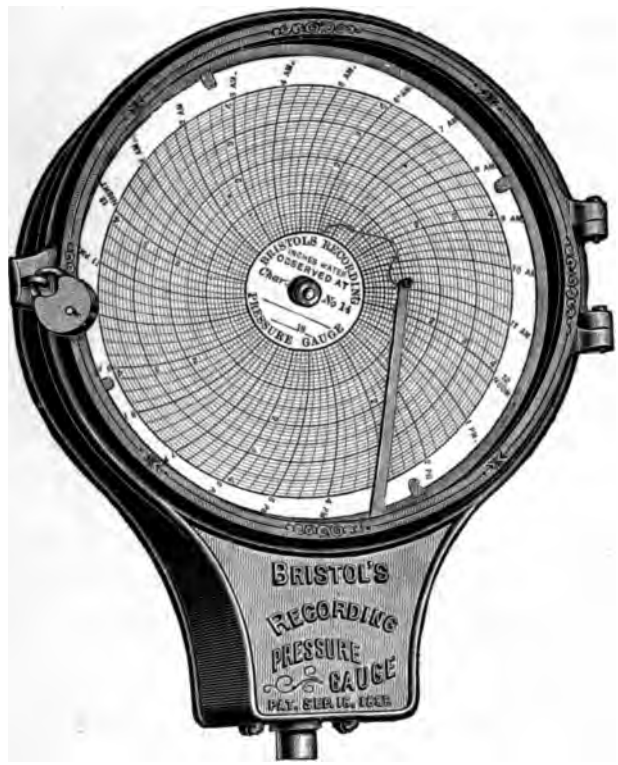


FIG. 3.

As in the sinuous tube, the motion thus produced by variations of pressure is ample for directly indicating or recording in connection with a moving chart. By the use of a large number of diaphragms, as shown, it is evident that the change of form of each individual member is very slight for complete range of pressure.

It follows that none of the diaphragms will be strained to their elastic limit, and all danger of the gauge taking permanent sets will be avoided. In the application of the diaphragm tube to a recording gauge it is mounted on a back as shown in Fig. 2.

A recording pen is attached directly to the end of the diaphragm tube, and a clock is provided, as shown, timed to revolve a dial, in the plane of movement of the pen, once in twenty-four hours.

In Fig. 3 the gauge is shown complete, with chart, ready for application. The small graduations on the chart indicate tenths of inches head of water.

This form of tube is not limited to recording gauges for light pressures only, as it could be equally well adapted for all ranges if the diaphragms are properly proportioned as to size and thickness of metal.

There are other practical applications of this form of tube, if constructed on a large scale, as considerable motion and power could be developed; sufficient, it is believed, to operate directly, without intervening mechanism, regulators, dampers, valves, and especially that class of automatic devices in which pressure is the initial motive power.

DISCUSSION.

Mr. R. Van A. Norris: I should like to ask Mr. Bristol if he has ever applied his gauge to record the pressure used in ventilating buildings or mines. The Pennsylvania law requires coal operators to keep automatic records of either the speed of the ventilating fans, or of the water gauge, usually depression, in them. It strikes me that Mr. Bristol's gauge could be applied to record this, which is usually between the limits of one-quarter inch and 4 inches water gauge.

Mr. Bristol: That is an application which has not yet occurred to me, because I have never had any connection with mines or mining methods. I can see no reason why it would not be applicable to such a place. I would like to ask Mr. Norris what the range of pressure is.

Mr. Norris: From one-quarter to probably three-quarters of an inch water gauge. Occasionally, the pressures will run as high as 5 inches; but that is very rare. I know of only one instance, in my experience, of a 5-inch water gauge in Pennsylvania.

Mr. Bristol: The gauge in its present form, as exhibited, has a total range of 4 inches head of water, and would, I believe, be directly applicable for recording pressures used in mine ventilation. If it should, an exhaust of from one-quarter to 4 inches which it is required to have recorded, the same instrument could be adapted by placing the flexible strip on the opposite of the system of corrugated diaphragms, so that the exhaust or suction would produce a deflection to the right, the same as is now produced in the model by pressure (Fig. 3). Exhaust has a tendency to shorten the system of diaphragms; and, as that tendency is resisted by the flexible strip, a multiplied lateral deflection will be produced. The direction of the deflection will be opposite to that produced by pressure; it therefore follows that the instrument may be arranged to record both exhaust and pressure upon the same chart, if desirable. I expect there will be many applications developed as Mr. Norris now suggests. I am very glad of an opportunity to learn of this.

Mr. Jesse M. Smith: I would like to ask Mr. Bristol whether there is any temperature correction necessary. If the instrument were placed in a room, say at 60 degrees, and the temperature went up to 70 or 80 degrees, will there have to be a correction on account of that change of temperature? I would also like to ask whether he has used this instrument as an air thermometer for continuous use in measuring the temperature of the gases escaping from a boiler.

Mr. Bristol: The only applications that have been made thus far are the measurement of pressures of gas in street mains; but from the experiment just made, I can see no reason why the instrument would not be applicable to the measuring of temperature of furnace gases, since the instrument itself would not have to be exposed to high temperatures. It could be at one side; and it is only a matter of arbitrarily graduating the chart, once for all, to

suit the volume of air that is in the pipe leading to the gauge, by some standard thermometer. The pressure would practically only be affected by the temperature of the furnace gases themselves. I expect to perfect a thermometer for high temperatures; and, if necessary, will provide for the effect of changes of atmospheric temperature. Answering the other question, as to the effect of temperature on the instrument when used as a pressure gauge, would say, that I have not made any actual experiments, other than taking a Bunsen burner and applying the flame directly to the tube itself, and noting whether the extreme temperature changed its form. I could not see that it did. That would be about as severe a test as you could possibly give it. (Applying flame of Bunsen burner to model.) You see, even with extreme heat directly applied to the tube, the indicating hand does not move from the zero point.

From this experiment, I concluded that any ordinary atmospheric change of temperature would not affect it. The result would be simply a cubical expansion which is about 18 or 19 millionths for a degree.

Mr. James Hartness: I would ask Mr. Bristol if the same result would be accomplished in case he left that pipe plugged up, or if he applied heat to that tube connected with the pressure gauge?

Mr. Bristol: I expect that the tube will be deflected, as the apparatus is in condition to act as a thermometer. As there is a considerable volume of air confined in the tube itself, upon heating the tube, it will be expanded, producing a pressure which will act on the tube, and make it deflect. I will try the experiment. I have not tried it before (applying the flame of a Bunsen burner directly to tube of model, the outlet being closed). I can see the indicator hand move; it moves about one-eighth of an inch.

Of course, that is an extreme temperature. I have applied, probably, a difference of 100 degrees, in the tube itself, which is probably more than you would have, in any place where the instrument would be put, due to atmospheric changes of temperature.

When the instrument is applied as a pressure indicator, or recorder, as, for instance, on a street gas main, any effect of atmospheric temperature would have to produce a difference throughout the whole system before there would be any difference indicated by the gauge.

Mr Ball: One more question. This instrument seems to be almost perfect. The question has just occurred to me, whether the scale of the instrument would be affected by heat. We notice that when heat is applied to the diaphragms, with the pointer at zero, no motion takes place; if, at the same time, the instrument were used in the usual manner, would the resulting record be the same as when the diaphragms are cold ?

Mr. Bristol: It is all a question of whether the elasticity of the metal is changed by an ordinary change of temperature. I cannot answer the question. I cannot see any reason why it should be; though, of course, if we should heat the diaphragms up to anything approaching red heat, they would lose their elasticity. Within moderate ranges, I believe that element would not appear.

Mr. Henning: I would say that experiments made by Professor Marten, show that up to 950° Fahr. there are no changes in elasticity; that metals show the same modulus and limit of elasticity up to at least 950° Fahr. Beyond that, there might be minute variations; but there would be no changes for temperature within which the instrument itself could exist.

COST OF CASTINGS.

FROM a "pamphlet on the cost of castings" prepared for the Foundrymen's Association, by Mr. Stockton Bates, of the Manufacturers' Club of Philadelphia, the following tables with the introductory letter, have been taken.

The "pamphlet" contains definite information and useful suggestions on methods of ascertaining the actual cost of cast-iron manufactures, from the pig to the delivered product, and presents the various forms of reports and statements employed in each of the departments of some very extensive establishments, all systematically arranged and indexed. ED.

PROVIDENCE, R. I., May 12, 1892.

MR. HOWARD EVANS,
Secretary "Foundrymen's Association,"
1056 Beach Street, Philadelphia, Pa.

DEAR SIR: Your letter of May 10 is at hand, for which we thank you. The reason we have not sent you our report of the cost of castings more promptly, is because the data we had on hand was collected a long time ago when we were new in the foundry business. We have a very intelligent young man, a graduate from Stevens Institute, who has been with us some time: to him we have intrusted the looking up of this matter, and enclose herewith his report. He is going to repeat the process in a short time again, in order to prove his first work. We send you also two of our cupola blanks, one filled out as we fill it out every day, and the other blank. These you can keep, but when through with the report, we would thank you to return it to us.

Hoping this may add somewhat to your line of investigation, we are, Yours truly,

BROWN & SHARPE MFG. CO.

R. VIALL, Superintendent.

Date, May 9, 1892. No. D. Cupola.	Coke.	Pounds Coal.	No. 1 Lehigh.	No. 1 Lowmoor.	No. 1 Chickie.	No. 1 Poughkeepsie.	No. 1 Thomas.	No. 1 Anniston.	No. 1 Sheridan.	Scrap.			Pounds Scrap.	Pounds Sprues.	Pounds at Each Charge and Total.	Remarks.
Charge	1,475	.....	280	340	710	355	460	200	280	1,375			.....	.....	4,000	
Added	425	.....	.....	340	330	200	180	200	100	650			.....	.....	2,000	
"	285	.....	.....	340	330	200	180	200	100	650			.....	.....	2,000	
"	490	.....	.....	680	660	400	360	400	200	1,300			.....	.....	4,000	
"	380	.....	.....	680	660	400	360	400	200	1,300			.....	.....	4,000	
"	190	.....	.....	340	330	200	180	200	100	650			.....	.....	2,000	
"	250	.....	.....	425	412	250	225	250	125	813			.....	.....	2,500	
"	350	.....	.....	425	412	250	225	250	125	1,113			.....	.....	2,800	
Pounds of each	4,045	.....	280	3,570	3,844	2,255	2,170	2,100	1,230	7,851			.....	.....	23,300	
Blast put on	3.30	1 Pound Coal Melted 576 Pounds Iron.														
Iron flowed	.....															
Blast to iron	M	PRESSURE OF BLAST IN OUNCES.														
		Time.	Time.	Time.	Time.	Time.	Time.	Time.	Time.	Time.	Time.					
Dropped bottom	5.35															
	H. M.	Oz.	Oz.	Oz.	Oz	Oz.	Oz.	Oz.	Oz.	Oz.	Oz.					
Blast to drop of bottom	2–5	7½														

BROWN & SHARPE MFG. CO.,
Providence, R. I.
Recorded by G. A. RAY.

Condition of Metal.		Poor.	Medium.	Sharp.	V. Sharp.
Castings.	Sprues, Etc.	Total.	Short of Charge.	Defective Castings.	
Pounds	Sprues, 3,750 Waste, 540 Shot, 600	4,890			

DETERMINATION OF COST OF PRODUCTION OF CAST IRON AT THE SPOUT OF THE FURNACE.

The cost of production involves the cost of labor, material, wear and tear of cupola and attachments, repairs and interest on first cost of the same.

To find the material going in the cupola, more than enough pig, scrap and coke was weighed than would be used in the heat, and after the heat the unused material was weighed. The wood was measured.

To find the iron coming out, the ladles were weighed as they left the cupola full and as they came back empty. The difference

TABLE NO. 3.—COKE USED.

COKE WEIGHED FOR USE.			COKE LEFT OVER.
Weight.	Weight.	Weight.	Weight.
199	250	234	270
258	253	280	311
278	305	271	235
248	273	265	292
266	280	247	.....
275	257	260	.....
1,524	1,618	1,557	1,108
		1,618	
		1,524	
Total coke weighed for use.....		4,699	
		1,108	
Coke used....		3,591	

in these weights plus what stuck to the ladles, and what was spilled and drooled before reaching the scales, gave iron coming out of the spout.

The iron stuck to the ladles was found by weighing the crucibles before the heat and again after the heat. The spilled and drooled was swept up, riddled and weighed.

The iron which remained in the cupola immediately before the bottom was dropped, was, when cool, separated from the slag and ashes by rattling and weighed.

The following is a set of tables giving the material used:

TABLE NO. 1.—PIG USED.

Brand.	Weight Already on Platform	Weight Brought In.	Total on Platform by Brand.	Weight Left Over.	Weight Used by Brand.
Lowmoor	532	3,488	4,020	575	3,445
Chickie	915	3,003	3,918	717	3,201
Poughkeepsie	2,051	1,020	3,071	962	2,109
Thomas	1,580	771	2,351	443	1,908
Anniston	421	2,304	2,725	728	1,997
Sheridan	741	869	1,610	579	1,031
Lehigh	382		382	382	
Totals					13,691

TABLE NO. 2.—SCRAP USED.

SCRAP WEIGHED FOR USE.								SCRAP LEFT OVER.	
Scrap Barrow.	Barrow.	Scrap Barrow.	Barrow.	Scrap Barrow.	Barrow.	Scrap Barrow.	Barrow.	Scrap Barrow.	Barrow.
357	88	546	95	420	88	393	88	846	115
407	83	471	88	353	95	219	88		
294	95	221	77	430	88	293	77		
344	77	356	88	345	95	323			
476	88	553	77	390	95	337	88		
403	77	532	77	557	88	592	95		
						521	115		
2,281	508	2,679	502	2,495	549	2,678	551	846	115
						2,495	549	115	
						2,679	502		
						2,281	508	731	

Total weight of scrap and barrows	10,133	2,110
" " " barrows	2,110	
Total weight for use	8,023	
Scrap left over	731	
Total scrap used	7,292	

Table No. 4.—Iron From Spout.

Before and After Heat.		Weight of Ladles Full and Empty During Heat.									
Weight of Ladle Before.	Weight of Ladle After.	Full.	Empty.	Full.	Empty.	Full.	Empty.	Full.	Empty.	Full.	Empty.
273	443	322	271	321	275	311	157	279	216	308	182
124	272	331	135	794	124	316	455	272	166	312	220
126	111	1,028	131	1,044	430	233	145	283	157	387	187
157	152	317	427	312	150	803	140	302	168	332	188
121	132	338	165	308	187	300	276	841	179	539	325
130	129	281	127	341	148	317	174	347	545	363	277
150	150	329	273	267	130	285	189	288	188	292	190
149	184	788	131	795	159	285	136	284	130	333	173
295	157	312	126	326	278	560	120	290	128	350	183
235	135	346	122	331	213	402	153	296	130	1,017	126
125	129	1,055	133	289	161	330	203	321	134	323	200
122	125	306	435	319	136	770	135	344	129	312	208
184	235	322	170	1,069	189	351	480	547	152	315	157
431	301	292	136	353	131	297	156	251	126	275	430
.....	. ..	754	350	328	125	350	126	292	122	782	155
.....	.....	326	126	349	122	779	277	49	144	....	.....
.....	.....	336	145	309	152	319	145	1,050	22	.....	.....
.....	.....	315	193	316	170	320	23	320	425	.. ..	.....
.....	... ..	544	426	298	171	253	151	310	138	.....	.....
2,622	2,656	8,642	4,022	8,489	3,451	7,581	3,641	6,966	3,399	6,240	3,201
	2,622									6,966	3,399
	34									7,581	3,641
										8,469	3,451
										8,642	4,022
										37,898	17,714
										17,714	

Iron delivered from ladles	20,218 *
Iron stuck to ladles	34
Total iron from spout	20,218 *
Iron recovered from cinders	265 †
Total accounted for from cupola	20,483

* This figure used in calculating costs.

† Weight of iron from cinders after dropping bottom and rattling iron and barrow, 380; barrow, 115.

COST OF MATERIAL, LABOR, ETC.

Lowmoor...	3,445	pounds at	$19.60	+	12	cents for piling	per ton,	$30.37
Chickie.....	3,201	" "	19.25	"	"	"	"	27.69
Poughkeepsie.	2,109	" "	19.02	"	"	"	"	17.99
Thomas, No. 1,	1,908	" "	17.48	"	"	"	"	14 96
Anniston.....	1,997	" "	18.10	"	"	"	"	16.22
Sheridan	1,031	" "	19.25	"	"	"	"	8.91
Total cost of pig....								$116.14
Scrap, 7,292 pounds at 70 cents per cwt.....								51.04
								$167.18
Scrap recovered from cinders, 265 pounds at 70 cents per cwt.								1.85
Total cost of iron....								$165.33
Wood, ¼-cord at $4.50.....								1.12
Coke, 3,591 pounds at $6.50 per ton (short).....								11.66
Labor, cupola gang.....								7.60
Deterioration of plant per year.....							$100	
Repairs, clay, brick, etc., "							300	
Charged against cupola.....							$400; per day. ..	1.11
								$186.82

Cost per long ton.....	$20.62
" " short ton...	18.48
" " pound.....	.000924

H. J. SCHUMACHER, M. E.

THE FIRST AMERICAN IRON CASTING.

"AN humble prototype of the great iron industry extending over our country," was the designation given to the first iron casting made in America, a kettle, which was recently presented to the municipality of Lynn, Mass., by Mr. John E. Hudson, of Boston, a lineal descendent of Mr. Thomas Hudson, the original owner of the kettle.

At the presentation exercises, Mr. C. J. H. Woodbury delivered the following interesting historical address:

"A few months ago, I learned that Messrs. Arthur and Llewellyn Lewis, the owners of the kettle well known as being the first casting made at the Saugus Iron Works, were seriously considering the acceptance of one of several offers recently made for its purchase, and as it appeared to me that this article, which was the precursor of the vast iron industry in American, should be kept at Lynn, where it properly belonged, as a relic most closely affiliated with the early history of our town, I at once purchased the kettle.

"The Saugus Iron Works were such an important factor in the inception and early development of American industries, that their early history merits due consideration. This was not the first attempt at iron smelting, but the first success. The iron works were located at Saugus, on account of extensive deposits of bog iron in the Saugus meadows.

"The master mechanic of the works, Joseph Jenks, brought over from England to fill the place, because he was one of the best workmen of his day, made good his reputation in this country. In the year 1654, he built for the town of Boston the first fire engine made in America.

"When Governor John Endicott began the Oak tree and the Pine tree coinage, in 1652, the dies were made by Joseph Jenks at the Saugus Iron Works. It is stated by Judge James R. Newhall that the designs were made by Elizabeth, the wife of Joseph Jenks, the master mechanic. This coinage, bearing the stamp 'Massa

chusetts State,' without any reference to the throne, was probably the first fundamental act of independence to the mother country. The colonists were driven to such a course by the lack of money, as exchanges were for the most part carried on in barter, with bullets and wampum serving for small coin.

"Joseph Jenks also invented a sawmill, which received a patent for 14 years from the General Court on June 10, 1646, being the first patent granted in America; and also a water engine for mills, which was undoubtedly a form of water wheel, and not the hydraulic engine which that term would now signify.

"He also invented the modern American scythe, long and narrow and stiffened by a ridge along the back, a marked improvement 'for the more speedie cutting of grasse' over the broad, short bush-whacker scythe made from a thin plate of steel, and richly deserved the patent for seven years, which was granted by the General Court, May 23, 1655."

APPLICATION OF AIR BRAKES AND AUTOMATIC COUPLERS.

BY EDWARD B. WALL, M. E., '76.*

CONGRESS did not pass a law, at its last session, on the application of air brakes and automatic couplers, although the House of Representatives passed the O'Neill bill, which would have become a law if the Senate had agreed to it, and had not had a bill of its own. If the session had been a little more protracted, it is very probable that an agreement would have been reached between the two bodies, and we would have had a compulsory law. The indications are, from the interest engendered, that a law will be enacted at the next session; and it therefore behooves us to consider the probable character of such a law, and what steps we should take in the construction and repair of our equipment, to the end that we may not at

* From *The Locomotive Engineers' Journal.*

least do anything which will increase, rather than diminish, the cost of adding new appliances to our cars and engines. We might as well make up our minds that there is going to be a law; and, with this in view, we would be blind indeed, if we did not take every step to alleviate the burden on our companies, of what will, at best, be an enormous expense.

The bill passed in the House stipulates that all locomotives in the interstate traffic shall be equipped with driver brakes by July 1, 1895; and that no new locomotives shall be put in such traffic without driver brakes after July 1, 1893. The Senate bill simply provides that all locomotives shall be equipped by January 1, 1895.

On automatic brakes for cars, the House bill requires that all cars shall be equipped by July 1, 1898—six years—and that no new cars, or cars which have received general repairs since the passage of the act, shall be hauled without such brakes after July 1, 1895—three years. The Senate bill modifies this greatly. It stipulates that by January 1, 1895, there shall be a sufficient number of cars in a train equipped with automatic brakes to enable the train to be controlled without hand brakes, and says nothing about the further equipment of the cars.

On couplers, the House bill enacts that all cars shall be equipped by July 1, 1898—six years—and that no new cars which have received general repairs since the passage of the act shall be hauled without automatic couplers after July 1, 1895—three years. These provisions are the same as those for air brakes. The Senate bill places the limit for the equipment of all cars at January 1, 1898—five and a half years.

It will thus be seen, that when a law is passed, we will probably be given from two and a half to three years in which to equip locomotives with driver brakes; from five and a half to six years to equip cars with couplers; six years in the House bill to equip all cars with air brakes, and five and a half years in the Senate bill to equip about one-third of the cars. I estimate one-third, as this is safe to estimate of the number which experience has shown would be required to meet the conditions stipulated by the Senate.

In order that this burden may be spread over as long a period as possible, and that we may not have to undo what we are to-day doing, it is essential that we should adopt a policy which will cover the following:

1. All new locomotives shall be provided with driver brakes. It would be well, where the company is able, to further issue instructions that driver brakes shall be placed on all locomotives receiving general repairs. The close agreement between the Senate and House on a very short allowance of time to accomplish this work, points to the fact that we will be greatly hurried, if we do not begin now. It may be said, for this expenditure, that there are few other investments on a railway that will bring such immediate beneficial returns.

2. All cars built henceforth should be equipped with air brakes. No matter how poor the road, they will be the victims of the most short-sighted economy, if they do not adopt a brake rigging on all new cars that will operate with the air brake.

It has now become generally understood, that the air brake cannot be made to perform its functions with the old brake rigging in use on cars provided simply with hand brakes. The Master Car Builders' Association has, happily, solved this part of the problem for us. They adopted a brake rigging in 1889 that has successfully met the requirements of service, and is now universally adopted, whenever air brakes are used on freight cars.

3. All cars built in future should be equipped with automatic couplers. Where companies cannot afford this, as in the case of air brakes, they should adopt a draft rigging that will receive the automatic coupler by simply removing the old draw-bar and tail-pin and putting in the new coupler with its tail pin.

4. In repairing cars, all old draft rigging removed should be replaced with new draft rigging designed to receive the automatic couplers. This should even be done on very old cars—cars that have, say, but two years left of their life, because the rigging will then, in most cases, be available for use in repairs.

5. The application of couplers to cars now in service should be at a rate, irrespective of any probable law of Congress, equal to the consumption of the present draw-bar. This condition would entail on many railways an expense that they could not at present bear; but for those who can meet the condition, it would be greatly to their advantage.

The five and a half to six years which Congress proposes to grant, represents a little more than the life of the present draw-bar, which I estimate at from four to five years. It must be recognized

that such an estimate is only tentative, on account of the present very large admixture in service of automatic couplers, and the constantly increasing number of consolidation engines and heavy cars, together with due consideration for the difference in kinds of metal used, and in the designs of draw-cars.

6. All automatic couplers purchased should be subject to the proposed tests of the Master Car Builders' Association, which stipulate that couplers shall meet a certain drop and tensile test. This secures good and safe malleable iron, cast steel and wrought iron. The M. C. B. type of automatic couplers has now reached such a stage of development that thoroughly good couplers can be purchased from several manufacturers. The M. C. B. coupler has become a regular article of commerce. It is so simple a matter to devise a slightly different form from any now in service that it can never become a monopoly. If we hold him up to the M. C. B. tests, the quality will not decline to the danger. After the coupler has been longer in use, there will be no necessity for the liberal guarantees now given by some of the coupler companies.

7. All automatic brakes should conform to the standards of efficiency proposed by the Master Car Builders' Association. A number of air-brake companies are now preparing to put new systems and new devices on the market; and every railway company, for its own protection, and to secure interchangeability in operation and maintenance with other railways, should stipulate before introducing a new brake that it shall meet the standard requirements, not only in effect, but in fact, as determined by a test on a rack and also on a train.

It is not our purpose here to criticise the two bills before Congress, or to point out how they might be changed in order to accomplish the end desired with a minimum of hardship to the railways. A large majority of the railways are in favor of automatic brakes and couplers. This is proven by what they have done and are doing. They believe in them for the safety they bring to their employees and the improvement they afford in transportation. What they have done has been done of their own volition, and, if left to themselves, most of the railways would add the brake and coupler appliances as fast as their revenue warranted.

Both branches of Congress have very wisely proposed to reach a settlement of certain points in their bills through the American

Railway Association, and it is to be hoped that when they enact a law, they will also make that association the vehicle through which the vote is taken on a standard coupler, or, if they do not, that the association will cast the vote of the railways included in its organization. This will simplify the matter greatly for the Interstate Commerce Commission, and will enable the railways to act with a uniformity and decision that would be otherwise impossible.

THE NEW CHEMICAL BUILDING.

WHILE less progress has been made than was hoped or is desirable in securing the funds required to erect a new building, or such a portion thereof as would warrant the commencement of the work, the purpose and effort have by no means been abandoned; but, on the contrary, steps have been taken to secure and render permanent a steady and continuous movement in this direction.

Such amounts as have come in, from time to time, have been deposited in the Hudson Trust and Savings Institution, where the fund draws 4 per cent. interest, and is under the joint control of Professor Riesenberger, as representing the Alumni Association, and President Morton, as Secretary of the Finance Committee of the Trustees, where it will remain securely and gradually increasing, until such time as the amount necessary for the erection of a chemical building shall have been accumulated.

It rests with the Alumni and other friends of the Institute to shorten this time; but, be it long or short, a new chemical building (and if means enough can be secured, a building for the department of physics also) will be the final result; and, meantime, every contribution received is doing its part, directly, and by the interest it earns, towards the desired and most desirable end.

The amount received so far is $6,025.72, including certain subscriptions worthy of special note, such as the following: From Prof. Coleman Sellers, E. D., $200; from Mr. E. D. Leavitt, E. D., Superintendent of the Calumet & Heckla Mines, $250; Mr. Thomas

Dolan, head of the firm of Thomas Dolan & Co., the great woolen manufacturers of Philadelphia, who, as President of the United Gas Improvement Co., has employed a large number of the Institute graduates, and has thus had an opportunity of observing its good work.

We mention these contributions in particular. because they encourage us to hope for a like interest among others, outside of the circle of the Alumni.

It is with the immediate view of securing aid in this direction, that the following circular has been prepared and distributed among our Alumni, by the Executive Committee, with the request, that it should be used in such ways as its contents indicate.

ALUMNI ASSOCIATION OF THE
STEVENS INSTITUTE OF TECHNOLOGY.

DEAR SIR: In view of the fact that you are more or less directly interested in the supply to the manufacturing interests of the country, of well-trained mechanical engineers, competent to take charge of the construction, erection and operation, of all sorts of machinery, we think that you may be willing to give a little time and attention to the following statement:

About 20 years ago the Stevens Institute of Technology entered upon the then new field of preparing young men for the profession of mechanical engineering; and, between that time and this, there have graduated about 400 men, who now hold responsible and useful positions as foremen, draughtsmen, superintendents and managers in machine shops, railroad shops and manufacturing establishments throughout the country. In many cases, these men are the engineering heads of the establishments with which they are connected; and, as a class, they have achieved such a standing, that many of our large manufacturers employ as a matter of course graduates of this Institute, whenever they desire to add to their force or to fill a vacancy.

As a natural result of this, for many years past, demands for admission have considerably exceeded the capacity of the Institute, and, as a result, many worthy applicants have been rejected, simply for want of accommodation.

To meet the difficulty, a plan was inaugurated, and an appeal issued by the Alumni Association of the Institute, for the erection of a building at a cost of some $50,000, for the accommodation of the Chemical and Physical Departments, and nearly $20,000 have been subscribed by the Alumni and a few friends. The funds as received are deposited in a savings bank, where they draw 4 per cent. interest, and are under the joint control of the Finance Committee of the Trustees and the Assistant Treasurer of the Institute, who are pledged to see that this money is applied to the erection of the aforesaid building.

We would desire you to have this situation in mind and to think of it in connection with the fact that the success and profit of your business depends to some extent on the supply of well-trained mechanical engineers as well as on the supply of sound raw material and good coal, and that money invested in aiding the production of either of these "supplies" may be well invested in a business sense, even if it brings in no direct return.

The original endowment of the Institute, compared with the work done and now doing, was very small; and, although the number of students has more than doubled, the endowment has not been increased.

There is nothing to prevent the Trustees from connecting the name of the donor with any considerable gift, so that the foundation of a professorship, a department, or the erection of a building to be known by the name of any donor, would be a condition of the donation, which would be readily carried out.

Subscription blanks are enclosed, and we trust the matter will receive your favorable attention.

Very truly yours,

THE EXECUTIVE COMMITTEE.

PHILIP E. RAQUÉ, *Corresponding Secretary*,
Times Building, N. Y.

I hereby subscribe the sum of
Dollars, $ to the building fund of the Alumni Association of the Stevens Institute of Technology to be applied to the erection of a new Chemical and Physical building.

Name,
Address,

When the matter was first discussed it may be remembered that there was a general plan to erect a building which should accommodate *both* the departments of Chemistry and Physics. As the plans were matured, however, it became manifest that these two departments could be best provided for in two wings or separate parts of the new building, and from this it naturally followed that in view of the more pressing need of new space for the chemical laboratories, it was contemplated to build the chemical wing or building first, if means for both could not be secured at the outset. This is, then, the present understanding and plan.

ANNOUNCEMENTS BY THE EXECUTIVE COMMITTEE OF THE ALUMNI ASSOCIATION.

At a meeting of the Executive Committee, held on January 11, 1893, it was decided to hold the midwinter meeting of the Alumni Association on the evening of February 15, at which time the new constitution will be presented for approval, and matters relating to the Alumni Building Fund will be brought up for consideration. Arrangements for the social features of the evening, with collation, will be made by a special committee, and the Executive Committee earnestly hope that there will be a large attendance of the Alumni.

At a special meeting of the Executive Committee of the Alumni Association of the Stevens Institute, held at the office of the Field Engineering Company, Central Building, Liberty and West Streets, New York City, Tuesday evening, November 22, 1892, for the purpose of receiving evidence and determining the facts in the controversy between Alumni Trustee William Kent and Gus C. Henning *et al.*, the following decision was reached:

Whereas, At a meeting of the Alumni Association of the Stevens Institute of Technology, held Wednesday evening, June 22, 1892, Alumni Trustee William Kent alluded to a circular letter

issued by four members of the Association asking the Alumni to concentrate their votes on certain other four members for Alumni Trustees, and

Whereas, The four members, Messrs. Gus C. Henning, R. S. Kursheedt, Albert Spies, and C. W. Thomas, who issued the above circular letter, objected to Mr. Kent's remarks, and in reply thereto caused to be published in the columns of THE STEVENS INDICATOR of July, 1892, their strong disapproval of Mr. Kent's remarks, accusing him of making several "gross misstatements," uttering "untruths," and "certainly and outrageously prostituting his official position as Alumni Trustee," and

Whereas, These two publications led to a lengthy controversy between the members interested without prospects of a settlement, Mr. Kent finally appealed to the Executive Committee, in his official capacity, for an adjustment of the case.

Therefore, In compliance with Mr. Kent's wishes, and with the consent of the other four gentlemen involved, the Executive Committee made a thorough investigation, received evidence from both sides to the controversy, and

Resolved, That it is the sense of this committee that while Mr. Kent's statement as to the embarrassment caused by the issuing of the circular in regard to the election of Alumni Trustees, is somewhat misleading, and that he made a partial error in regard to the votes cast as to one or two candidates, that, after listening to all of the evidence presented, they find no ground for the allegation that he made several "gross misstatements," or that he made remarks that were "untrue," or that he "certainly and outrageously prostituted his official position as Alumni Trustee."

And it is Further Resolved, That the expressed desire of Mr. Kursheedt to reach an amicable settlement is heartily endorsed and recommended to all parties in interest.

The above resolutions were proposed by Mr. E. B. Renwick, and seconded by Mr. Robert M. Dixon, and in the resulting vote Messrs. Joseph Wetzler and E. S. Cronise voted in the negative.

It was moved by Mr. Cronise, seconded by Mr. Wetzler, that the resolution as passed at this meeting of the Executive Committee, be placed on record as publicly as the original letters and statements leading up to the controversy.

Carried.

In order to avoid any such occurrence in the future it was further

Resolved, That the Executive Committee strongly disapprove of using the columns of the INDICATOR for personal controversies.

MINORITY OPINION.

JANUARY 19, 1893.

Executive Committee, Stevens Institute Alumni Association.

GENTLEMEN: In voting "No" to the resolution passed after the special meeting, called to take evidence in the Kent-Henning controversy, we desire to explain that our reasons for dissenting were, that having in view the probable far-reaching effect of any action by the Executive Committee in this matter, and to avoid the possibility of criticism or charges of hasty action, we desired to refrain from a final judgment until the complete stenographer's report was received, and a decision could be arrived at, based upon a careful analysis of all the evidence submitted.

This is simply a repetition of our remarks at the adjourned meeting, held immediately following the closing of the case, but we wish this minority opinion to go on record in the INDICATOR along with the resolution above referred to.

Yours truly,

ERNEST S. CRONISE,
JOSEPH WETZLER.

THE CARRIAGE BUILDERS' SCHOOL.

AT the 20th annual convention of the National Association of Carriage Builders, held at Buffalo, N. Y., on October 25 and 26, Mr. Franklin Murphy, of Newark, N. J., Chairman of the Committee on Technical Education, read the report of the Secretary of the Carriage Builders' School, in which appreciative mention was made of Dr. Morton's interest in their work, and of the lectures delivered before the School by Dr. Morton, Professors Denton and Webb, and Dr. Dudley.

Mr. Murphy then presented the report of his committee as follows:

At a meeting of the Association, held last year in Cincinnati, the proposition to raise the standard of work done at the school by placing its supervision under the faculty of the Stevens Institute, was decided upon after a very full discussion, and your committee were charged with carrying out the details incident thereto.

During the fall, by personal interview and correspondence with the faculty of the Stevens Institute, arrangements were made for the delivery, during the winter, of a course of lectures before the school, on mechanical subjects of special interest to carriage builders, the idea being that they were to be treated from a sufficiently simple standpoint to be useful to the students.

Dr. Morton and his associates took great interest in the plan, and did all that was possible to insure its success. Some time was consumed in the preparation of the lectures, and a special effort was made by the committee to develop an interest in them among the students, as well as to add to their usefulness by securing larger audiences than the school would naturally furnish. These audiences were sought for among the various carriage factories in New York City and vicinity. In accordance with the plan the course of lectures was opened by Dr. Morton, and continued by several of the professors, and a special lecture by Dr. C. B. Dudley on painting was also given. The value of these lectures must

be admitted by all who heard them, and yet it cannot be denied from a practical standpoint that their success was not as great as was hoped for. The committee found that the members of the school were as a whole not as far advanced in their education as they had supposed. Not far enough indeed to make it desirable for the school as constituted to do anything more than continue lessons in carriage drawing. Almost without exception the attendants were apprentices or mechanics who worked during the day and who gave three nights each week to our school to learn carriage drawing. Their situation was such that they could hardly be expected to do much more; and so it was thought advisable by every one interested in the matter to attempt to do nothing further, but continue the school upon its original basis, and present a statement of the condition of affairs to the Association for their action at this time.

Your committee are of the opinion that the time has come when a technical school of the very first quality should be provided for the carriage builders of the country. That is not a technical school which we now have in New York City. That school is simply a school of carriage drawing, and if the suggestion of your committee is carried out, the present school will be added to the proposed school, and will be continued without change, except in its location, which will be transferred to Hoboken.

The death of Professor Gribbon in the middle of the school term strengthened the feeling of the committee that the time had come when some permanent change should be made. They had several interviews with Dr. Morton and his associates with this end in view, the result of which was a proposition from him to establish in the Stevens Institute of Technology, at Hoboken, a carriage makers' school which would give to the sons of carriage builders, and any others who desired, the advantage of that well-equipped Institute. The following is Dr. Morton's proposition:

"I have been talking over the details of plans for the addition of a carriage builders' department with Professor Denton, and others, and we have evolved the following schedule of what we could do if the means were provided:

"1. We would keep up evening classes in drawing and designing for the benefit of workmen and apprentices, like those heretofore carried on by the Carriage Builders' Association.

"2. We would provide special instructions in connection with our regular course in drawing and descriptive geometry, in such lines as are required in carriage building.

"3. We would in the same way provide (in connection with our Department of Applied Mechanics) special instruction in the application of the principles of statics and dynamics to suitable problems in carriage building.

"4. In our shopwork course we should introduce as exercises in carpentry the principal joints used in carriage construction, and some special tempering exercises relating to carriage springs.

"5. Again, in our experimental course we would introduce a number of exercises especially valuable to the future carriage builder or manager of a carriage building establishment; such as testing the strength of the joints and frames of principal forms of carriages; test of different forms of springs; test of strength of wheels, etc.

"In fact, as far as this is concerned, we would provide what would be, in our estimation, as complete and practical a course for the young man who wished to be a thoroughly educated carriage building engineer as he would get in a college established for that purpose alone.

"This would involve, however, his thorough preparation and subsequent study while here, in such subjects as would enable him to rank with other mechanical engineers or like professional men. The requirements of those who did not aim so high would be met as heretofore, by the night classes.

"In connection with these, moreover, we would arrange for courses of lectures by specialists like Dr. Dudley, which would be open to all students and members of the Carriage Builders' Association, and which would constitute contributions to the scientific literature of the subject.

"To carry out such a programme as above would of course involve a considerable outlay and constant expense, since this sort of instruction has never been self-supporting.

"Our own work, as you know, is in a large measure supported by the endowment of our founder, which amounted altogether to nearly a million dollars.

"Under ordinary circumstances it would be impossible for us to give the space and service necessary to carry out such a scheme;

but it opportunely happens that, having reached the extreme limits of our present accommodations, and having been obliged to refuse large number of students for that reason, we have just inaugurated measures to raise funds to erect a new building and otherwise enlarge our facilities.

"In connection with this movement it will not be difficult for us to provide the additional accommodations and facilities needed to carry out the programme outlined above, providing your Association is willing to provide the same.

"Our estimates for yearly expenses are as follows:

Special instruction in drawing	$1,500
Extra compensation to Professors of Drawing and assistants	500
Extra compensation in Department of Applied Mechanics	500
Care of room for Night Class and special Drawing Class, lighting, heating, repairs, etc	600
Special lectures and apparatus for same	500
	$3,600

"In addition to this, some substantial contribution should be made to our building fund, as we will be obliged to provide additional space for the proper handling of the night classes, and the appliances for the special instruction in the subject of carriage building.

"In order that your Association should have something to represent their contribution, we would agree to give them a perpetual scholarship for each $5,000 so contributed.

"In view of the fact that the proposed plan would secure to your Association, in our opinion, as great advantages as could be secured by the establishment of a special school, which would involve not much less than $1,000,000 for endowment and building, I do not think that the above estimate of cost is otherwise than very moderate."

This proposition is supplemented by a subsequent letter from Dr. Morton, in which he says: "As regards such students, you do not, perhaps, understand our financial position. So far from being a source of profit, each student draws on the income from our endowment, and the large increase in their number, without corresponding increase in our endowment, would ruin us. The income of $5,000 will be the cost of a student, and scholarships are often

vacant, and thus we can afford to give a scholarship for $5,000, and while we are willing to do all that we can to aid you, we cannot undertake what would amount in the end to a serious load without adequate support. As I have said before, what your Society needs is a special school, but the establishment of such a thing on an adequate basis would involve not much short of $1,000,000. We believe that we can secure you something substantially equal for about 10 per cent. of that amount, but not for nothing, nor do we see how our aid to you can be a source of profit to ourselves. If your school as a body, or if any of its individual members, are disposed to put money into a carriage builders' school, we will help them to get the most for the investment; but it does not present itself in the light of a profitable speculation to us."

The committee are unanimous in their hope that arrangements may be made which will permit them to accept this proposition. They believe it is the greatest opportunity that has ever been presented to the carriage trade. To accept it will be to give the carriage builders, practically a special technical school, unequaled in the world, so fully equipped for doing good work that its usefulness is almost beyond estimate. At the same time, it provides for the continuance of the present school as an evening class in Hoboken instead of in New York, and as the location of the school in Hoboken is fully as convenient to the central part of New York as is the present situation in the Bowery, there is every reason to hope that the present school transferred to Hoboken can be continued there with undiminished usefulness.

But the essential feature of Dr. Morton's proposition lies in the fact that he proposes to establish a school of the highest character for the sons of carriage builders who desire scientific and practical training to fit them in the fullest degree to succeed their fathers, or to enter any other business well equipped for success.

Your committee are under the impression that a total fund of $85,000 would be sufficient for the purpose of meeting Dr. Morton's views, from which the necessary annual income may be provided. If the Association think it best to assume the responsibility of providing this fund, your Committee on Technical School are willing to undertake to raise the sum needed, providing they can be assured of the cordial support and help of the Association.

FRANKLIN MURPHY, *Chairman.*

The reading of the foregoing report was received with applause.

Mr. Murphy (continuing): Before I take my seat, I desire to read a letter from Dr. Morton to Mr. Ogden, which follows a personal interview of Mr. Ogden with the Doctor, which is dated October 23. He says:

"STEVENS INSTITUTE OF TECHNOLOGY.

"HOBOKEN, N. J., October 23, 1892.

"MY DEAR MR. OGDEN: Since writing you yesterday, I have seen Professors Denton and Riesenberger and have gone over with them the figures in detail, with the following result:

"If we were to inaugurate the night school this year, and carry on in connection with such preparatory work as would be desirable with the view of providing a special course in connection with our regular one for students who were to take responsible positions in carriage building establishments, it would cost us about $3,600 for the year.

"By submitting to considerable inconvenience we could handle this night class in our present building for this season, but before next fall some additional buildings will be absolutely necessary.

"By working in connection with the new buildings which we will be then erecting for our present classes, we could make such special structures for about $15,000.

"If, therefore, the carriage builders are serious in their intention of doing anything towards establishing a special course of education for their students, and desire our aid, I think that it is only reasonable that they should take steps to raise a fund which would enable them at least to pay for the building and special apparatus connected therewith, which would be required for their accommodation. This arrangement had best be extensible, so that, if in future, the success of the work warrants it, an adequate endowment for a Carriage Building Department might be provided.

"As I explained in my former letter, we are not in the position of a concern with idle capital and plant on the lookout for new business, but rather of a firm with a business which strains their plant and capital to its full capacity, who are willing to contribute

their experience, etc., towards developing a new business, provided those interested in the latter will supply the plant and capital necessary for carrying it on.

"Very truly yours,

"HENRY MORTON."

Mr. Murphy (continuing): I think perhaps I ought to read one more paper for the benefit of those who are not familiar with just the situation at Hoboken, and I will read from the *Scientific American* of June 18 a short notice in regard to this institution. It begins by saying:

"If any one should turn back to the volumes of the *Scientific American*, between 1871 and 1873, they would find various notices of the Stevens Institute of Technology, then being established in Hoboken, N. J., in which we took a lively interest as being the first institution devoted exclusively to the training of mechanical engineers in this country, and we may indeed say in the world, if we take account of the special combination of theory and practice involved in its course of instruction; because in no school before had there been any such combination of the theoretical development of the science of mechanical engineering on a mathematical basis with the practice of the same science as carried out in the foundries and workshops.

"We naturally looked upon the experiment then and there inaugurated with the deepest interest and most cordial sympathy, because we saw how important to the prosperity of those mechanical industries on which our National prosperity rests would be the success of this undertaking, which aimed at nothing less than the education of young men in a way that would fit them to go into the workshops of the country, and supply the much needed theoretical knowledge derived from the recorded experience of others with the aid of the potent tools of mathematical methods and practical familiarity with the machines and processes to be handled.

"The two factors supplied for the solution of this problem were: A bequest of money and ground, amounting in all to about $750,000, made by Mr. Edwin A. Stevens, and a faculty of young and energetic professors, headed by President Henry Morton, who had already distinguished themselves in their various departments.

"It is now 21 years since this experiment was begun, and as we look at its results to-day we see our brightest anticipations and most sanguine hopes more than realized.

"Graduates of the Stevens Institute are filling positions of the greatest responsibility in the workshops and great industrial enterprises of the country, and are in demand beyond the capacity of the Institute to supply them, and on the other hand, applicants for admission have for several years so much exceeded the capacity of the Institute to accommodate them that considerable numbers have been refused admission, not for lack of adequate preparation (though the scholastic standard has been constantly raised), but because there was absolutely no room to hold them."

Mr. Murphy (continuing): That is the institution, Mr. Chairman and gentlemen, from which it is proposed to secure the benefits of this new enterprise. I perhaps will make this whole matter clearer if I state, briefly, in two or three minutes, just what the proposition is before you. It is not to abandon your present school—it is to continue that as a night school the same as it is now, at Hoboken, under the supervision of the teachers who shall conduct this new and broader school. It will provide the carriage makers of the country with the finest technical school in the world, as it will result in sending the sons of carriage builders of England, France and Germany to complete their education in this country. There will be no school in the world where the carriage builders' sons will be as well equipped as in this school, if Dr. Morton's idea is carried out. This $15,000 is contributed to the building fund, in order that the room necessary for the carriage trade may be provided for. If you capitalize that it would be $70,000, and it is thought by the committee it would be better to capitalize it, so as to relieve the Association from the obligation of providing this sum from year to year. If that could be done, then the Association would be relieved from any further responsibility in regard to it. If, upon the other hand, it is not thought best to provide the endowment fund, but to assume an obligation, to provide $3,600 a year, in addition to this $15,000, that, I think, would be acceptable to Dr. Morton. It is really a great opportunity for this Association, and the committee, in presenting it, feel that they have accomplished at least something in being able to bring before this sociation such a proposition.

An animated and favorable discussion followed, closing with a resolution authorizing the committee to endeavor to raise the necessary endowment fund, and Messrs. Franklin Murphy and W. W. Ogden were requested to formulate a plan for securing the fund.

Mr. C. F. Kimball, of Chicago, the President of the Association, is himself a college bred man, having graduated from Bowdoin College in 1874, and then taken a two years' course in Columbia Law School. He began in 1877, at the age of 23, in Chicago, the career in carriage building which has made his house famous wherever fine carriages are used; and he has won personal recognition as one of the ablest and most popular members of the Association.

The recent editorial of the *Scientific American*, quoted herewith, upon the contemplated course of the Carriage Builders, is not without interest, as indicating clearly some of the advantages to be derived by the traveling public, as well as by the carriage trade, from a realization of the proposed plan:

The National Association of Carriage Builders held their 20th anniversary recently in Buffalo, N. Y. Among the subjects treated a particularly important one, and interesting in view of the general movement for the advance of technical education, related to the establishment of a carriage builders' technical school. For some time past a school has been maintained in New York City for the education of young men employed in the carriage factories, apprentices and mechanics who work during the day. These young men gave three nights each week in the carriage builders' school to learn carriage drawing. This is the work that has been done. The Carriage Builders' Association, however, felt that more was required, and advocated the establishment of a true technical school.

As the representative of practical technics in this vicinity, the Stevens Institute at Hoboken afforded an obvious opening for the foundation of such a course. The Institute for many years has graduated from its curriculum engineers in the true, practical sense of the term. Its graduates are not only familiar with the mathe-

matics of the subject, with the theory and scientific aspect of their work, but are also practical workmen when they leave it. Special provision is made for giving them a course in practical mechanics so that they may learn the absolute use of tools. After they leave the college there is no need for them to spend a year or more in the shop. This part of their education is included in their college course.

The faculty of the college have taken a special interest in the carriage builders' school, such as it is. It seems very natural, therefore, that by a slight addition to its force, the Stevens Institute of Technology might supply the needed college for carriage builders. Evening classes in drawing and designing should be kept up for the benefit of workmen and apprentices. Instruction in connection with the regular course in drawing and descriptive geometry would be included in such lines as are required in carriage building. Under applied mechanics the application of the principles of statics and dynamics to suitable problems in carriage building would be given. In shop work the joints used in carriage construction and the tempering of springs are two suggested topics. In the experimental course special examples in testing the strength of springs, joints and frames would be introduced.

Such in general, with added lectures by specialists, is the programme as suggested by Dr. Henry Morton, the President of the Institute. To carry it out, money is required, and the collection of such money is now being attended to by the Association, and they seem to believe that they will succeed in raising a sufficient capitalization to enable the Stevens Institute of Technology to establish the special course designed.

The situation of the Stevens Institute of Technology is particularly available, being so readily reached by ferries both up and down town in this city. Its peculiar fitness as a center of such instruction has been already explained. A carriage builders' school established there will have the advantage of a score of years' preceding work done at the Institute, for into the work of the course will enter the experience of the entire faculty. The work done by a regular student in that department will to a great extent be the same as that done by all, so that he will receive the full benefit of the plant of the Institute and of the long years of work of its faculty.

Carriage building is rapidly developing and bids fair to become a true profession. The past year has witnessed remarkable results obtained by the introduction of ball bearings and pneumatic tires on racing wagons, and it is hard to believe that the day is not near at hand when vehicles of luxury will be thus equipped. In the structural department electricity is already playing a part in the welding of tires and in the welding and brazing of joints in general. All this indicates the invasion of the old field of handiwork and apprenticeship by the highly trained mechanic and technologist. The carriage factory may yet be called upon to supply electrically propelled vehicles. Many experimental vehicles of this type have indicated the possibility of future success. In the use of oil fuel and of naphtha engines there is also a possibility for the future. In carrying out these and many other impending changes the educated technologist will find in carriage building full scope for an engineer's education.

INSTITUTE NOTES.

IT HAS BEEN arranged to hold an entrance examination in June, as well as in September this year. Notice of the dates will appear in the catalogue and in the next number of the INDICATOR.

AMONG THE Stevens Alumni in attendance at the regular annual meeting of the American Society of Mechanical Engineers were Professors Wood, Webb, Denton, Riesenberger, Bristol and Jacobus, also Messrs. Robert N. Bayles, Henry A. Bang, James M. Creamer, E. S. Cronise, George Dinkle, H. L. Gantt, G. C. Henning, F. E. Idell, William Kent, W. L. Lyall, Dabney H. Maury, Lewis H. Nash, H. De B. Parsons, Phillip E. Raqué, R. H. Rice, E. P. Roberts, J. M. Rusby and Albert Spies.

Among the papers presented were the following: by Professor Wood, "Hydraulic Reaction Motors" and "Negative Specific Heat;" by Professor Jacobus, "Experimental Determination of the Heat Generated per Candle Power in Oil and Gas Lamps;" by Professor Bristol, "A New Recording Pressure Gauge for Extremely Low Ranges of Pressure."

WHEN PROFESSOR UNWIN was in the United States last fall, in the interest of the Cataract Construction Company, he spent some time at the Institute, and was entertained at dinner at the Engineers' Club, by Professors Jacobus, Denton and Riesenberger, who invited a small company of representative engineers to meet the distinguished visitor, those present being Mr. William Fletcher, of the W. & A. Fletcher Co., builders of the steamer "Plymouth," etc.; Mr. William H. Wiley, of J. Wiley & Sons, Treasurer of the American Society of Mechanical Engineers, and American correspondent of London *Engineering;* Professor H. W. Spangler, Professor of Engineering, University of Pennsylvania; Mr. Maunsel White, M. E., Engineer of Tests, Bethlehem Iron Works; Mr. A. R. Wolff, M. E., Heating and Ventilating Engineer; Professor F. R. Hutton, Professor of Mechanical Engineering, School of Mines, Columbia College, and Secretary of the American Society of Mechanical Engineers; Mr. H. M. Montgomery, engineer of L. Schutte & Co, Philadelphia, Pa.; Mr. Wiliam Kent, M. E., Mechanical Expert, and Mechanical Editor, Appletons' Cyclopedia; Mr. E. H. Foster, M. E., Engineer, H. R. Worthington Hydraulic Works, representative at the Paris Exposition in charge of the firm's exhibit.

In evidence of his appreciation of courtesies then extended him, Professor Unwin has forwarded to Professor Jacobus, a portrait of Mr. James Forrest, Secretary of the British Institute of Civil Engineers, to whose unremitting zeal the great success of that Institute is very largely due.

This portrait Professor Jacobus has presented to the Institute, and it has been placed in the library.

THE THOMSON ELECTRICAL BALANCE presented to the Institute by the Class of '86, has arrived in good order; and has been assigned a prominent position in the Electrical Laboratory, by Dr. Geyer, who has ordered a plate with appropriate inscription prepared for it.

THE INSTITUTE has recently been presented by Capt. H. E. Tarr with a steel plate portrait of the late Henry R. Worthington, inventor of the celebrated Duplex Pumps, and founder of the manufacturing firm whose business in pumping engines and water meters is still conducted under his name; also with one of the late James Simpson, Esq., a widely-known engineer, who was one of the earliest builders of pumping engines in Great Britain. These portraits now adorn the Institute Library.

PROFESSOR SELLERS' lectures were, as usual, of the greatest practical value. Shop Sizes, Drawing Room Practice, Machine Shop Practice, Mechanical Calculators, and the Management of Men, were some of the subjects treated. Lectures of especial interest were those in which he told of the novel engineering problems encountered by the engineers of the Cataract Construction Company, in undertaking to utilize a portion of the vast power available at Niagara Falls; and explained the methods adopted, illustrating the subject by numerous sketches and blue-prints.

The eager interest with which the lecturer was followed by the professors and visitors present, as well as by the students from several classes, attested their appreciation of his thorough knowledge of the subject he so simply and clearly explained. It is hoped that the INDICATOR will be able in an early issue to place before a wider audience many of the facts and illustrations Professor Sellers referred to in these lectures.

PROFESSOR DENTON has been elected a member of The American Society of Civil Engineers, and member of The American Shipmasters' Association, which is an equivalent organization to The American Lloyds.

PROFESSOR THURSTON, of Cornell, has also been elected to membership in the American Shipmasters' Association.

AT THE STATED meeting of the Franklin Institute, in Philadelphia, December 21, Dr. Sellers presented a communication regarding the Priestman engine.

Cassier's Magazine for November reprints in full Professor Stillman's paper on "The Analysis of Cylinder Deposits," which appeared in the October number of the INDICATOR. Another article in the same number of the INDICATOR, that by Professor Jacobus, on "Calculation of the Heat of Combustion of an Illuminating Oil Gas, and Comparison with the Heat Determined by Experiment," has been copied by *The American Gas Light Journal.*

A MOST enjoyable occasion was the reception tendered to the Junior Class on October 25 by Dr. and Mrs. Albert R. Leeds, assisted by the Misses Gaehr, Angell and Parker.

IN *Stevens Life* of January 12, the publication is commenced of some of the schemes in quantitative analysis prepared by Dr. Stillman for the Junior Class, beginning with the analysis of limestone.

AT A MEETING of Stevens Engineering Society, on January 20, papers were read by Mr. Brookfield, '93, on "Platinum," and by Mr. Axford, '93, on "Mechanical Methods Used in Butchering."

At the meeting on February 3, Mr. Mackenzie presented a paper on the "Manufacture of Calico," and Mr. Chandler one on "Locomotive Construction."

The officers are: President, R. E. Chandler, '93; Vice-President, M. O. Slocum, '93; Treasurer, A. B. Lord, '93; Secretary, A. G. Wilbor, '94.

STEVENS PHOTOGRAPHIC SOCIETY will give its annual exhibition jointly with the Sketch Club, on February 6. President, E. R. Douglas, '93; Secretary, C. T. Rittenhouse, '93; Treasurer, J. A. Goldsmith, '93.

THE MEMBERS of the Sketch Club, though few in number, show such an energetic spirit and enthusiastic co-operation, as to insure for the *Link* of 1893 sketches of equal if not superior merit to those of bygone years. All students who sketch are relied upon to join the Society, and lend their aid in embellishing the publications, for their own benefit and the credit of the Institute. A very creditable exhibition by this club is promised, in connection with the Lantern Slide Exhibition by the Photographic Society, in the High School Hall, February 6.

STEVENS SOCIAL SOCIETY.—Officers: President, B. G. Braine, '93; Vice-President, Thomas Cuming, '95; Secretary, H. E. Griswold, '93; Treasurer, J. V. Macdonald, '93.

The first dance of the season took place in Stevens School Hall, Tuesday, November 29, 1892. Notwithstanding the unpleasant weather there was a large attendance of the fair sex.

The patronesses were Mrs. Dr. Morton, Mrs. Dr. Leeds, Mrs. Kellogg and Mrs. Harrison.

The following ladies were present: Miss Sands, of New York; Miss Abbett, Miss Post, of Jersey City; Miss Cary, Misses Griswold, of Orange; Misses West, Miss Kellogg, Miss Dara, Miss Weir, Miss Simpson, of Elizabeth; Miss Spier, Miss Duer, Miss Speyers, Miss Gurney, Miss Schwartz and Miss Braine.

STEVENS GLEE CLUB.—Last year the Glee Club was a pronounced success; and it can be said without hesitation that still better things are expected of it this year. With but very few exceptions all the old members have returned, and the new material is of such a quality as to insure great success for the coming season.

The Glee Club sang at the Fair of the Columbia Club, on November 30, and together with the Banjo Club, assisted at a concert in the High School on December 5 in aid of St. Katherine's Home. Both clubs united in a concert given at Crescent Hall, Jersey City, on January 31, under the auspices of the Jersey City Lawn Tennis Club, and have arranged for a concert on February 20 at the Quartet Club Hall in Hoboken, for the benefit of the Stevens Athletic Association.

The officers are: Leader, William B. Osgood Field, '93; President, George P. Hodgman, '93; Secretary and Treasurer, A. G. Kollstede, '94; Manager, M. E. Craft, '94.

STEVENS BANJO CLUB.—The Banjo Club is working faithfully. Arrangements have already been made for giving several concerts in connection with the Glee Club, and notably the one in Hoboken, February 20.

The officers are: Leader, G. M. Maynard, '95; President, H. E. Griswold, '93; Secretary and Treasurer, H. B. Cook, '93; Manager, M. E. Craft, '94.

THE CHESS CLUB has received large accession to its membership from the Class of '96, which bids fair for increased attention to this game in succeeding years. Its officers are: President, B. G. Braine, '93; Vice-President, Frederick J. Angell, '94; Treasurer, Frederick Opperman, '94; Secretary, T. M. Bennet, '96.

THE STEVENS GUN CLUB proves a popular organization, as attested by increasing membership.

The officers elected January 12 are: President, W. B. Osgood Field, '94; Vice-President B. H. Cameron, '94; Field Captain, Lattimore Carter, '95; Secretary and Treasurer, E. P. Buffett, '94; Director, H. D. Summerhayes, '96.

At the fall match, Mr. Field won first place among 20 contestants, and Mr. Summerhayes was second, the prizes being a handsome double-acting revolver and a Swedish hunting-knife. Frequent matches are proposed for the spring.

STEVENS YACHT CLUB.—The Yacht Club has entered upon the second year of its existence under the most encouraging circumstances. The membership reached the limit early last spring; and, notwithstanding the loss of several members, a waiting list of considerable length is now in the hands of the secretary. In all probability the limit will be raised at the next meeting in order to accommodate a large number of Freshmen who are desirous of joining. At the last meeting it was proposed to give a dance. After considerable discussion it was decided to abandon the project, and give in its stead a boating party on the day of the naval parade in May next, when a steamer will be chartered, and the club will entertain its guests in true nautical style. The treasurer reports a large surplus which is drawing interest in a savings bank. At the annual election the old officers were re-elected almost without exception. The officers for the year are as follows: J. Winfield Gilmore, Commodore; A. A. Dal Molin;

Vice-Commodore; A. G. Kollstede, Rear-Commodore; A. M. Lozier, Secretary; W. W. Ward, Treasurer; G. F. Gilmore, Fleet Captain.

Several members have signified their intention of building during the coming spring. On the waiting list are the owners of a steam yacht and two sloops.

DURING the latter part of November an energetic member of the Class of '95 started the movement towards establishing an eating house, where students could be sure of being well served, and where all could get meals in the same house, thereby promoting college spirit. This would afford a fitting place for a training table, where those assigned to it would be envied, and others would have the apparent inducement to hard and conscientious work to make the team, and gain the honor of sitting at the *training table*. A well-known caterer made overtures to obtain the patronage of the students practically as a body, and arrangements to fit up a suitable house on Washington Street, near Eighth, were about completed, when a mass meeting was called in Professor Wood's room. This meeting took place in December, and at this meeting it appeared that the caterer, Mr. Lash, could not conveniently meet initial expenses, but with a subscription loan of $500 he would prepare to serve the students at a week's notice. The subscription was immediately started, the understanding being that subscribers would be repaid in board or cash within six month. In two days promises amounted to $300; but, when two weeks later, the small amount of cash forthcoming indicated a suprisingly meagre interest on the part of the undergraduates, no one can wonder that Mr. Corbett, '95, gave up, though reluctantly, all hopes of establishing that keenly felt want of Stevens students, a common eating house or a "commons."

THIS year's *Link* will be embellished by sketches from the pen of Wildman, '90.

AMONG the exhibits at the World's Fair in Chicago, one that will attract attention, and elicit comparison with the electric launches, which are to provide quick transport over the waterways, will be a *fac-simile* of the twin-screw steamboat built by Mr. Stevens in Hoboken in 1805. The original boiler and engine used in that steamboat, and which have been preserved at the Institute as relics, will be placed in this reproduction. In connection with this exhibit, the Hoboken Land and Improvement Company will also send a model of the Hamburg, the latest double-screw boat built for the ferry between New York and Hoboken.

"I KNOW OF NO OTHER INSTANCE where a father and his sons have left behind them such a remarkable record of usefulness." This was the well-considered statemen concerning John Stevens and his sons, Robert L. and Edwin A., made before the Philosophical Society of Washington, May 7, 1892, by Mr. J. Elfreth Watkins.

The occasion upon which this high tribute was rendered was the reading before the Society by Mr. Watkins of his paper, "Biographical Sketches," "John Stevens and His Sons," "Early American Engineers," in which are

presented the main achievements of this remarkable family, achievements in number and importance astonishing to any one who had not before seen them summarized.

This paper, forming a pamphlet of some thirteen pages, with portraits of the subjects of the biographies, and a *fac-simile* of the order given by "Robert L. Stevens, President and Engineer of the Camden and South Amboy Railroad and Transportation Company," November 26, 1830, for T rails, and of his sketch of the rail, which accompanied the order, Mr. Watkins has kindly notified Dr. Morton, he will forward to such of the Stevens Alamni as desire it, in so far as his limited supply will admit.

Alumni wishing the pamphlet should address Mr. J. Elfreth Watkins, No. 1801, Thirteenth Street, N. W., Washington, D. C.

ATHLETICS.

THE ANNUAL ELECTION of the Athletic Association was held January 10, resulting in the selection of the following officers: M. E. Craft, '94, President; G. B. Fielder, '94, Vice-President; William H. Corbett, '95, Secretary; Lattimore Carter, '95, Treasurer; W. B. O. Field, '94, H. D. Lawton, '94, Lewis Hardie, '96, Members of Executive Board.

BASE-BALL.

IT was decided to advocate and aid in supporting a base-ball team for 1893. Mr. Paulsen '93, has been elected Captain of the team, and he has appointed Mr. Merkel, '93, Manager.

FOOT-BALL.

THE retrospect of the season just closed is most pleasing and inspiriting.

We have put a better team in the field than for several previous years, and have made a record which may well encourage Stevens to hope for and work for even brighter laurels in succeeding years. This season, out of eight games played, we lost but two. This is a good record and should give an impetus to foot-ball in '93.

By the graduation of the Class of '93 we will lose only three men—Mackenzie, Griswold and Paulson—and, although we shall greatly miss them personally, there is a large amount of good material available to fill their places. Moreover, we anticipate valuable accessions when '97 comes into the Institute. So that, with the advantage of the practice and experience that our men have had last season, we have reason to believe we shall have a superior team in the field next year.

There is some talk of a league among Rutgers, Lehigh, Lafayette and Stevens. This would create a very interesting series of contests, and

awaken a corresponding enthusiasm for foot-ball in the college, which enthusiasm has too often been wanting in the past. This league would be superior in many ways to the one dissolved last year. All of those mentioned for members have about equally matched teams, and the championship would be closely contested.

Next year it is our hope to have a regular paid coach, which would be of great advantage. The men who kindly coached the team this year are: Marshall and De Hart, of the Orange Athletic Club, and Lewis, ex-tackle of Princeton.

Three 'varsity foot-ball games played since the last issue of the INDICATOR resulted in three victories, with the following scores:

Oct. 25, N. Y. A. C. *vs.* Stevens, at Hoboken; cancelled.
" 27, Fordham " " " score, 0–22.
Nov. 2, Rutgers " " " " 6–22.
" 5, Rensselaer Polytechnic Institute *vs.* Stevens, at Troy; score, 6–14.

STEVENS, 22; FORDHAM, 0.

The teams lined up as follows:

Stevens.	*Positions.*	*Fordham.*
Fielder	Left end	McCann.
Schumacher	Left tackle	Horan.
McIllwaine	Left guard	Callahan.
Gallaher	Center	Phelan.
Lord	Right guard	Delehanty.
Cuming	Right tackle	McCarshy.
Hamilton	Right end	Donahue.
Coyne (Capt)	Quarter	Ferguson (Capt.)
Mackenzie	Left half back	Boyle.
Brown	Right half back	Doran.
MacCord	Full back	Ramsey.

The Fordham team, with a goodly delegation of friends, came to Hoboken with the intention of running up a big score. The score was run up, but not to the happiness of the Fordhamites.

Seeing that it would be impossible to win from our team fairly, it seems as if the umpire decided to lay off our heavy center men, and then have Fordam buck the center thus weakened. But the game didn't work.

After a few minutes' play, Gallaher was disqualified, and McIllwaine went to center and Marshall to guard. Then Cuming was laid off, Schumacher taking his place, and Hutchinson playing left tackle. He, however, was soon disqualified, and Mackenzie was called into line, while Maynard played half.

First half.—Touch downs, Mackenzie, 1; goals, Mackenzie, 1. Score, Stevens, 6; Fordham, 0.

Second half.—Touch downs, Mackenzie, 1; Maynard, 1; MacCord, 1 goals, Mackenzie, 2. Score, Stevens, 22; Fordam, 0.

STEVENS, 22; RUTGERS, 6.

A sweeping victory for Stevens. The first time since 1878, and Rutgers has as good a team this year as ever. They came on the field in jubilant spirits, fully expecting an easy victory. No other game of the year caused so much excitement.

The play on both sides was exceedingly good, both teams playing to win at any cost. There were several long runs, noticeably those of MacCord, whose last long run down the field was the prettiest witnessed here in many a day.

The teams lined up as follows:

Stevens.	*Positions.*	*Rutgers.*
Koehler	Left end	Van Hee.
Hutchinson	Left tackle	Townley.
McIllwaine	Left guard	Tierney.
Gallaher	Center	Dyke.
Mackenzie, C.	Right guard	G. Ranney.
Schumacher	Right tackle	Ludlow, G.
Cuming	Right end	Loud (Capt.)
Coyne (Capt.)	Quarter	Tracy.
Mackenzie	Left half back	Ludlow.
Brown	Right half back	Van Duzer.
MacCord	Full back	McKnight.

First half.—Touch downs, Brown, 3; goals, Mackenzie, 2. Score, Stevens, 16; Rutgers, 0.

Second half.—Touch downs, Ludlow, 1; MacCord, 1; goals, Mackenzie, 1; Ludlow, 1. Score, Stevens, 22; Rutgers, 6.

STEVENS, 14; RENSSELAER POLYTECHNIC INSTITUTE, 6.

The last game of the season was played at Troy, November 5, and the men having again carried Stevens' colors to the front, went out of training, after the game, and enjoyed themselves immensely. The weather was cold for the Troy men; but we didn't mind it in the least. The R. P. I. team depended upon bucking our center, but they found a brick wall. The improvement of our center over last year is quite marked.

The team lined up as follows:

Stevens.	*Positions.*	*R. P. I.*
Griswold	Left end	Frazier.
Hutchinson	Left tackle	Mayers.
McIllwaine	Left guard	McPherson (Capt.)
Gallaher	Center	Edwards.

Marshall	Right guard	Magor.
Schumacher	Right tackle	Marcey.
Maynard / Mackenzie	Right end	Garland.
Coyne (Capt.)	Quarter	Givens.
Fielder / Brown	Left half back	Wilcox.
Cuming	Right half back	Hanavan.
McCord	Full back	Hine.

First half.—Touch downs, MacCord, 2. Goals, MacCord, 1. Score, Stevens, 10; R. P. I., 0.

Second half—Touch downs, Mackenzie, 1; McPherson, 1. Goals, McPherson, 1. Score, Stevens, 14; R. P. I., 6.

'95, 52; '96, 0.

At the class game, between '95 and '96, there was greater enthusiasm shown than at any of the other games. '96 went in with no hope of winning, their endeavor being to keep the score as low as possible. Seven '95 men were 'varsity players. Considering this handicap, and the fact that the captain of '96 could not get all his men together on a single occasion for practice, the score is no disgrace to '96. Maynard did most of the running for '95 and Louis for '96. Mathey did the best work for the defense. In the line the 'varsity men Hutchinson and Cuming got through oftenest.

The teams lined up as follows:

'95.	*Positions.*	'96.
Koehler	Left end	Jennings.
Hutchinson	Left tackle	Wagner.
Greenidge	Left guard	Mathey.
Keener	Center	Schweitzer.
Andrews	Right guard	Lancon.
Cuming	Right tackle	Strong.
Kirker / Willett	Right end	Gedney.
Kemble (Capt.)	Quarter	Chambers (Capt.
Brown	Left half back	Duehrina.
Hamilton	Right half back	Louis.
Maynard	Full back	Bull.

First half.—Touch downs, Koehler, 1; Hamilton, 2; Maynard, 2. Goals, Maynard, 5. Score, '95, 30; '96, 0.

Second half.—Touch downs, Brown, 1; Hamilton, 2; Maynard, 2. Goals, Maynard, 3. Score, '95, 52; '96, 0.

LACROSSE.

THERE is some talk of C. C. N. Y. applying for membership in the Intercollegiate Lacrosse League, composed of Stevens, Johns Hopkins and Lehigh. There is also a slight possibility of U. P. joining. Princeton and Lafayette will each have a team in the field this year.

The annual meeting of the League will be held in February. At this meeting the pennant will be awarded Stevens for last year's championship. Also a schedule of games for the coming season will be arranged.

H. Cuntz has been elected Captain of the team, but as yet no manager has been chosen. Those trying for the team will go in training this term. With the Class of '92 we have lost William C. Cuntz and Martin; but the other men of the team will be in better form and more experienced this year than last. We expect that Cuntz, '92, and Martin, '92, will come over and assist us as much as possible with their knowledge. If sufficient interest is displayed in the practice this year, it is under contemplation to procure the services of a second coach or rubber down to put the men in trim after practice every day.

CANE SPREE.

THE first annual cane spree between the Freshman and Sophomore classes was held on the cricket grounds November 7. The crowd that gathered to witness the contest was large and wildly enthusiastic.

The contestants were:

Light weight.....Butterfield, '95, 134 pounds...H. Hardie, '96, 134 pounds.
Middle weight.....Corbett, '95, 155 pounds.....Mathey, '96, 158.5 pounds.
Heavy weight.....Cuming, '95, 174 pounds.....Lançon, '96, 172.5 pounds.

The first contest, between the light weights, was settled in three rounds; victory for '95. Second, between middle weights, was the longest and most exciting of the day. At one time nearly all of '96 and '94 and part of '95 thought that Mathey had succeeded in getting the cane from Corbett, but the latter claimed a finger on; victory for '95. Third, between the heavy weights, was decided in only 15 seconds; victory for '95. After the spree '96 took revenge by capturing '95's flag.

Owing largely to the extraordinary indifference on the part of the majority of '96 to joining and supporting the Athletic Association, its income through dues and fees has been unprecedentedly small, and the end of the season found the financial statement with a balance on the wrong side of the account. Measures are on foot for making up the deficit by personal subscriptions, a concert, etc., but it is only by the general co-operation and support of the undergraduates that the Association can hope to carry the lacrosse team through next season in good shape; and upon their doing so depends our retaining the championship so gallantly won last year.

That the members of the lacrosse and foot-fall teams worked faithfully last year, at much personal inconvenience and outlay of time, no one

observant of their practice doubts. If every man in each class will but join the Association and push his pound, all will have good cause and a perfect right to yell for Stevens whenever the Stevens teams contest a game, and to participate in the victories our teams will then surely win.

REPORT OF TREASURER OF STEVENS INSTITUTE ATHLETIC ASSOCIATION.

STEVENS INSTITUTE ATHLETIC ASSOCIATION IN ℄c WITH H. D. LAWTON, TREAS.

Dr.		*Cr.*	
To Expenses of Lacrosse Team..	$352.60	By Balance from Former Treasurer..	$62.28
" Expenses of Foot-Ball Team.	405.25	" Net Gate Receipts:	
" Printing and Stationary.. ...	24.50	Base Ball Games.... $3.00	
" One Dozen Photographs of Foot-Ball Team.	18.00	Lacrosse Games..... 38.35	
" Cost of Framing Photographs	6.00	Spring Games..... . 18.11	
" Cost of Repairing Club House	3.80	Gun Club Match..... 2.50	
" Plumbing	6 30	Foot-Ball Games.. .. 117.80	
" Hardware	5.95	——	$170.76
" Miscellaneous Expenses.. .	13.25	" Initiation Fees from 12 New Members in the Spring..... $24.00	
" Lawn Tennis Club.....	10.00	" Initiation Fees from 36 New Members in the Fall.... .... 72.00	
Total Disbursements.....	860.81	" Dues from Old and New Members... ... 325.00	
Balance on Hand.....	66.98	——	$421.00
		" Locker Rentals..	9.25
		" Yearly Dividend I. A. A. A...	132.85
		" Balance from Foot-Ball Manager ('91)....	110.00
		" Sale of Photographs..... .. .	18.00
		" Miscellaneous....	3.65
	$927.79	Total Receipts...	$927.79

Outstanding accounts payable..... .... $200.00
Deducting balance in hand..... .... 66.98

Leaves deficit for year 1892..... . .... $133.02

HENRY D. LAWTON,
Treasurer S. I. A. A.

Steps are being taken to meet this deficit by subscription, and by a concert by the Glee and Banjo Clubs, on February 20, in Hoboken.

INSTITUTE PERSONALS.

'76.

A. R. WOLFF delivered a lecture before the Franklin Institute, of Philadelphia, on February 3, upon Heating and Ventilation of Large Buildings.

'77.

E. P. ROBERTS has resigned his position as Superintendent of the Swan Lamp Manufacturing Company; and, together with Mr. C. F. Uebelacker, E. E., has formed the firm of E. P. Roberts & Co., Mechanical and Electrical Engineers, Room 411, Western Reserve Building, Cleveland, O.

'78.

OSCAR ANTZ has accepted the Superintendency of the Cowles Engineering Company, foot of Forty-third Street, Brooklyn, N. Y. He resides at 56 Taylor Street, Newark, N. J.

'80.

WILLARD P. PARSONS, having accepted the Assistant Superintendency of the Southern Cotton Harvester Company, of New York, has resigned his position with the Trenton Steel and Iron Company.

'84.

WILLIAM S. ALDRICH has resigned his position as Assistant Superintendent to the William A. Harris Steam Engine Company, of Providence, R. I. His present address is 732 North Second Street, Reading, Pa.

A. W. BRAINARD is in charge of the New York office of the Bristol Manufacturing Company, at 121 Liberty Street.

DABNEY H. MAURY is taking a course of instruction in electricity under Dr. Geyer, and expects to subsequently utilize his knowledge of the subject in mining operations, a field in which he has had a large experience.

'85.

BARTON H. COFFEY has removed from Philadelphia to New York City, where his address is 142 East Fortieth Street.

ARTHUR G. GLASGOW is associated with Mr. Alex. C. Humphreys, '81, under the firm name of Humphreys & Glasgow, contracting engineers for water gas plants, office at Westminster Chambers, 9 Victoria Street, London, Eng.

'86.

EDWARD D. SELF has been for nearly a year in charge, as Superintendent and Chief Engineer, of the engineering work, at Paramaribo, Dutch

Guiana, of the Witte Water Placer Company, whose New York office is at 58 William Street. This company recently made large expenditures in the purchase of lands and machinery for working both quartz and alluvial gold deposits; and Mr. Self desires to correspond with some good Stevens graduates seeking that line of work, and who can stand the tropical climate.

'87.

J. H. CUNTZ spent the fall at Yale, taking many of the P. S. lectures on Political Economy, German Literature, Military Tactics, etc.

LEMUEL W. SERRELL, Jr., is Secretary of the United States Railway Company, 10 Wall Street, New York City.

'88.

NORMAN ST. G. CAMPBELL has severed his connection with the Baldwin Locomotive Works, and will have a temporary address at 212 South Forty-first Street, Philadelphia, Pa.

'89.

WILLEY J. FELTHEIMER is connected with the Sprague Electric Elevator Company, 114–120 West Thirtieth Street, New York City.

'90.

H. M. BRINCKERHOFF is Assistant Electrical Engineer of the Western Dummy Railroad Company, Chicago. His address is care of the Intramural Railway, World's Columbian Exposition, Jackson Park, Chicago

CARL H. GRAF is Superintendent of Gas Department in the Lawrence Gas Company, Lawrence, Mass.

J. F. HAWORTH is with Haworth & Dewhurst, Limited, wholesale grocers, at 701 Liberty Street, Pittsburg, Pa.

FREDERICK THUMAN sailed for London on the 12th of this month to enter the Engineering Department of the firm of Humphreys & Glasgow, contracting engineers for water gas plants, Westminster Chambers, 9 Victoria Street.

'91.

ALEXANDER DOW and G. S. PERKINS are with the Dow Type Composing Company, 31 East Seventeenth Street, New York City.

L. E. ELSON, who was in the employ of Charles B. Brush, C. E., at Hoboken, has accepted a position as the New York representative of the Beckit Foundry and Machine Company, of Arlington, N. J.

Mr. Elson lectured on The History and Development of Iron and Steel Shipbuilding at the Assembly Hall of the East Forty-second Street School, New York City, on December 15, 1892.

S. L. G. KNOX and H. W. SMITH have been elected to Junior Membership in the Amer. Soc. Mech. Engineers.

H. J. SCHUMACHER has resigned his position in the shops of the Brown & Sharpe Manufacturing Company, to accept the management of the Stamford Machine Works, Stamford, Conn.

HENRY A. WOLCOTT and JOHN DARBY, Mechanical Engineers, have established an office in the Hartford Insurance Building, Hartford, Conn.

'92.

HAROLD B. ATKINS is Assistant Electrician in the American Telephone and Telegraph Company, 18 Cortlandt Street, New York City.

F. W. COHEN is in the employ of the Pennsylvania Steel Company, at Steelton, Pa.

L. B. CORBETT is Secretary of the South Branch Manufacturing Company, manufacturers of chemicals from wood, Galeton, Potter County, Pa.

HAROLD HARRISON has associated himself with Mr. Power, of Montclair, N. J., agent for the Belmont Engine Company, Belmont, N. Y.

EDWARD L. JONES is Chief Draughtsman for the Crowell Clutch and Pulley Company.

WILLIAM O. LUDLOW is in the employ of Carrére & Hastings, architects, *Mail and Express* Building, New York City, the firm that built the Ponce de Leon Hotel at St. Augustine, Fla.

GEORGE H. MILLER is Inspector for the Middle States Inspection Bureau, 45-49 Cedar Street, New York City.

A. J. POST is with Post & McCord, architects, New York City.

JOHN T. SCHRAMME is a student in electricity at Columbia College, New York City.

A. SHIEBLER is with The B. F. Sturtevant Co. at their works, Jamaica Plain, Boston, Mass.

WILLIAM E. STRONG is Inspector for R. W. Hildreth & Co., New York City.

WILLIAM E. S. STRONG has entered the employ of the Howard Manufacturing Company, manufacturers of printing machinery, New Britain, Conn.

C. F. VOGELIUS is a student in electricity at Columbia College, New York City.

H. D. WHITCOMB, JR., has resigned his position with the Edge Moor Bridge Company, of Wilmington, Del., and is now Inspector for Hildreth & Co., of New York City, in their Philadelphia division.

'94.

D. W. BLAKE has joined the Stevens contingent at Cornell.

R. E. HALL has been obliged to leave the Institute, to travel a year for his health. He was engineering editor of "The Stevens Life," one of the Board of Directors of the Athletic Association, and was a member of the Senate, Glee Club and Junior Ball Committee.

BOOK NOTES.

LIST OF JOURNALS IN THE INSTITUTE LIBRARY.

American Chemical Journal. Baltimore, Md.
American Engineer and Railroad Journal, The. New York.
American Gas Light Journal. New York.
American Journal of Science. New Haven, Conn.
American Machinist. New York.
Annales de Chimie et de Physique. Paris.
Annalen der Physik und Chemie. Leipzig.
Anthony's Photographic Bulletin. New York.
Annalen der Chemie (*Liebig's*). Heidelberg.
Berichte d. Deutsch. Chem. Gesellsch. Berlin.
Bulletin de la Societè Chimique de Paris.
Bulletin of the American Iron and Steel Association. Philadelphia, Pa.
Bulletin of the New York Mathematical Society. New York.
Bleiblätter der Physik und Chemie. Leipzig.
Chemical News. London, Eng.
Civil Service Chronicle. Indianapolis, Ind.
Carriage Monthly. Philadelphia, Pa.
Cassiers' Magazine. New York and London.
Comptes Rendus. Paris.
Dingler's Polytechnisches Journal. Stuttgart, Ger.
Der Techniker. New York.
Electrician, The. London, Eng.
Electrical Review, The. London, Eng.
Engineer, The. London, Eng.
Engineering. London, Eng.
Engineering News. New York.
Electrical Engineer, The. New York.
Engineering Record, The. New York.
Electricity. New York.
Electrical World, The. New York.
Engineering and Mining Journal, The. New York.
Experiment Station Record. Washington, D. C.
Engineer, The. New York.
Franklin Institute Journal. Philadelphia, Pa.
Fortschritt der Zeit. Milwaukee, Wis.
Heat, Light and Power. Philadelphia, Pa.
Ice and Refrigeration. New York.
Industrial World. Chicago, Ill.

Industry. San Francisco, Cal.
Iron Age. New York.
Iron Age and Hardware Bulletin. New York.
Institution of Mechanical Engineers. London.
Journal of the American Chemical Society. New York.
Journal of Analytical and Applied Chemistry, The. Easton, Pa.
Journal of the Chemical Society. London, Eng.
Journal für Praktische Chemie. Leipzig.
Journal de Physique. Paris.
Journal of the Society of Chemical Industry. London, Eng.
Journal of Railroad Appliances. New York.
Journal of the New England Water-Works Association. New Bedford, Mass.
Journal of the American Society of Naval Engineers. Washington, D. C.
Journal of the Royal Society of New South Wales.
Journal of the Engineering Society. Lehigh University.
Lehigh Quarterly, The. Bethlehem, Pa.
Locomotive, The. Hartford, Conn.
Manufacturer and Builder, The. New York.
Mechanical News, The. New York.
Mining Journal, The. London, Eng.
Minutes of Proceedings of the Institution of Civil Engineers. London, Eng.
Mining News, The. Seattle, Wash.
Nature. London, Eng.
National Car and Locomotive Builder. New York.
New York Meteorological Observatory. New York.
Official Gazette, U. S. Patent Office. Washington, D. C.
Oil, Paint and Drug Reporter. New York.
Philosophical Magazine and Journal of Science. London, Eng.
Phrenological Journal. New York.
Power. New York.
Practical Mechanic, The. Worcester, Mass.
Progressive Age. New York.
Polytechnisches Central-Blatt. Berlin, Ger.
Proceedings Amer. Assoc. Advancement of Science. Salem, Mass.
Proceedings of The Royal Society. London, Eng.
Proceedings of The U. S. Naval Institute. Washington, D. C.
Proceedings of Engineers' Club of Philadelphia, Pa.
Railroad Gazette, The. New York.
R. R. and Engineering Journal, The. New York.
Railway Master Mechanic, The. Chicago, Ill.
Railway Review, The. Chicago, Ill.
Scientific American, The. New York.
Scientific American Supplement, The. New York.

Street Railway Journal. New York.
Stevens Indicator, The. Hoboken, N. J.
School of Mines Quarterly, The. New York.
Specifications and Drawings U. S. Patent Office. Washington, D. C.
Sibley Journal of Engineering, The. Ithaca, N. Y.
Textile Colorist, The. London, Eng.
Transactions American Society of Civil Engineers. New York.
Transactions American Institute of Electrical Engineers. New York.
Transactions American Society of Mechanical Engineers. New York.
Transactions American Institute of Mining Engineers. New York.
Transactions Engineers and Ship-Builders. Glasgow, Scotland.
Transactions of The Engineers' Society of Western Pennsylvania. Pittsburg, Pa.
Transactions of the Liverpool Engineering Society. Eng.
Transactions Technical Society of the Pacific Coast. San Francisco, Cal.
Zeitschrift für Analytische Chemie. Wiesbaden, Ger.
Zeitschrift für Augewandte Chemie. Berlin, Ger.

ACCESSIONS TO INSTITUTE LIBRARY, JULY 1 TO DECEMBER 30, 1892.

Books Purchased:

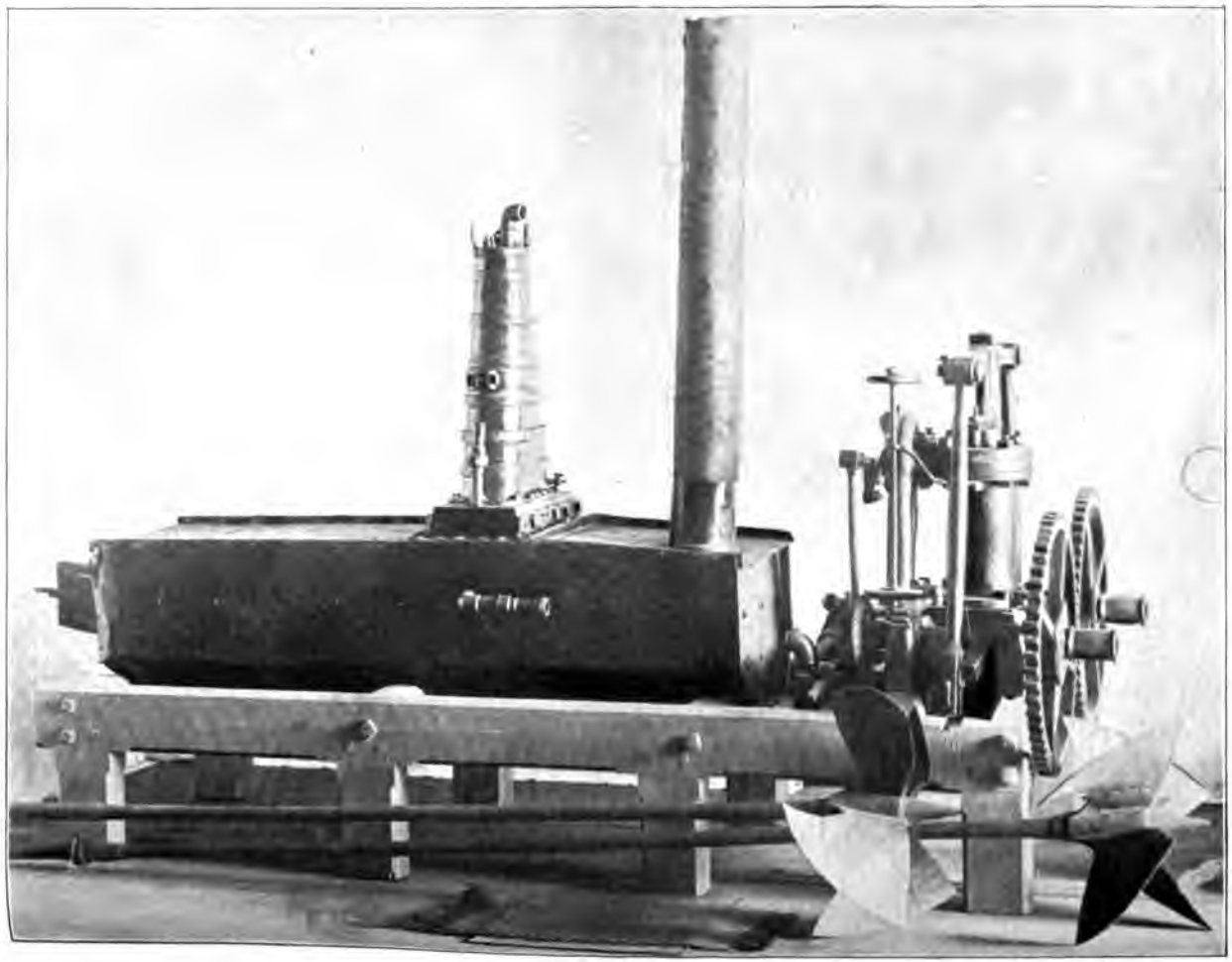
Minutes of Proceedings of the Institution of Civil Engineers. Vol. CIX.
Handbuch der Anorganische Chemie. Vol. I. By Dr. O. Dammer.
The Alternate Current Transformer. Vols. I. and II. By J. A. Fleming.
Dynamometers. By J. J. Flather.
Mechanical Drawing. By C. W. MacCord.
Street Railways. By C. B. Fairchild.
The Chemical Analysis of Iron. By A. A. Blair.
The Lives of Boulton and Watt. By Samuel Smiles.
The Life, Times, etc., of the Marquis of Worcester. By Henry Dirks.
A Treatise on the Steam Engine. By John Farey.
Universal Wiring Computer. By Carl Herring.
A Treatise on the Steam Engine. By John Bourne.
On The Cornish Engine. By Thomas Wicksteed.
Chemische Präparatenkunde. By Adolf Bender.
Jahrbuch der Chemie. By Richard Meyer.
Die Prüfung der Chemische Reagentien. By Dr. C. Krauch.
Commercial Organic Analysis. Vol. III., Part 2. A. H. Allen.

Die Imitationen. By Sigmund Lehner.
Chemiker-Kalender. By Dr. Rudolph Biedermann.
Hydraulischer Kalk und Portland Cement. By Dr. H. Zwick.
Anleitung zur Anwendung Physikalischer Methoden in der Chemie. By G. Kruss.
Analyt. Methoden zur Nahrungsmittel-Untersuchung. By Dr. C. Virchow.
Modern Locomotive Construction. By J. G. A. Meyer.

Contributed:

By President Morton. *Proceedings of The American Association for The Advancement of Science*, 1892.
By Professor Denton. *Ice and Refrigeration.*
By Professor Stillman. *Laboratory Manual.* By Delors Fall.
By Professor Jacobus. *Index of Current Engineering Literature.*
By A. A. Dal Molin. *Das Buch der Natur.* By Dr. Frederick Schoedler.
By Smithsonian Institute. *The Museum of the Future.* By G. Brown Goode.
By Smithsonian Institute. *Life Histories of North American Birds.* By Charles Bendire, U. S. N.
By Smithsonian Institute. *Smithsonian Report*, 1891.
By U. S. Department of Agriculture. *Experiment Station Record.*
By U. S. Department of Agriculture. *Notes on a New Method for the Discussion of Magnetic Observations.* By Frank Bigelow.
By U. S. Department of Agriculture. *Organization Lists of the Agricultural Experimental Stations and Agricultural Schools and Colleges in the United States.*
By U. S. Department of Agriculture. *Analysis of American Feeding Stuffs.* By E. H. Jenkins and A. L. Winton.
By U. S. Department of Agriculture. *Moisture and Crop Distribution.*
By U. S. War Department. *Report on the Climate of Arizona.*
By U. S. War Department. *Report on the Climate of California and Nevada.*
By U. S. War Department. *Report on the Climate of Colorado and Utah.*
By U. S. War Department. *Report on the Climate of New Mexico.*
By U. S. Department of State. *Reports of Consuls of the United States.*
By U. S. Patent Office. *Annual Report of the Commissioner of Patents.*
By U. S. Treasury. *Annual Report of the Comptroller.*
By U. S. Geological Survey. *Mineral Resources of the United States.* By David T. Day.
By U. S. Naval Observatory, Washington. *Observations*, 1888.
By U. S. Bureau of Steam Engineering. *Annual Report*, 1892.
By Massachusetts State Board of Health. *Report*, 1891.
By New Jersey Agricultural Experimental Station. *Analysis of Fertilizers.* By Ed. B. Voorhees.

By The Philosophical Society of Washington. *Bulletin*, 1892.
By Michigan State Board of Agriculture. *Report*, 1892.
By Wisconsin Academy of Sciences. *Transactions*, 1892.
By American Institute of Mining Engineers. *Transactions*; 1892.
By Rochester Academy of Science. *Proceedings*, 1892.
By Royal Society of Canada. *Proceedings and Transactions*, 1891.
The Diurnal Variations of Barometric Pressure. By Frank Cole, Ph. D.
The National Car and Locomotive Builder, 1887, 1888, 1889.



THE STEVENS INDICATOR.

VOL. X. APRIL, 1893. No. 2

THE FIRST STEAM SCREW PROPELLER BOATS TO NAVIGATE THE WATERS OF ANY COUNTRY.

BY FRANCIS B. STEVENS.

THE steam screw propellers of Col. John Stevens, in operation on the Hudson River from 1802 to 1806, were the first to navigate the waters of any country.

John Stevens was born in New York in 1749; was graduated at King's College, now Columbia, in 1768; was admitted to the bar of the Colonial Provinces of New York and New Jersey, in 1772; and was Treasurer of the State of New Jersey during the active period of the Revolutionary War. In 1784, he purchased Hoboken, then an island; and, residing there upwards of half a century, died in 1838.

On the 26th. of August 1791, patents for improvements in the steam engine were granted to John Fitch, James Rumsey and John Stevens. The latter took out three patents; one, for a method of propelling a steamboat by the reaction of water, and another, for a multi-tubular steam boiler.

In 1798 he was engaged with Chancellor Livingston, Nicholas J. Roosevelt and Isambard Brunel, then an exiled French royalist,

afterwards the builder of the Thames Tunnel, in making experiments on steam propulsion on the Passaic River, New Jersey. They tried a horizontal centrifugal wheel, on a boat of 30 tons, drawing water from the bottom of the boat and discharging it at the stern. This is similar to the plan that Ruthven tried in England on the "Water Witch," more than half a century afterwards. They also, unsuccessfully, attempted to use elliptical paddle wheels.

THE SCREW PROPELLER PREVIOUS TO 1802.

Water wheels for mills, driven by the action of a current of water against their vanes or blades, placed obliquely to the direction of the current, have been used in China for centuries; and in Spain, from the time of its conquest by the Moors.

Prior to the Revolution, they were in use in this country for mills; and were called Chinese sculls, or tub wheels. In principle, this wheel is identical with the windmill; and, when attached to a vessel, and driven by power applied to its shaft, it is the screw propeller.

Colonel Stevens, in his letter to Dr. Hare, given below, considered himself its inventor for the propulsion of vessels; but he was mistaken. It was proposed by the mathematician David Bernouli, in 1752; and it is described by David Bushnell, in a letter to Thomas Jefferson, dated 1787, giving an account of his submarine boat, to which this screw propeller, worked by hand, was applied; and of his attempt, with this boat, to blow up a 50-gun British ship in the harbor of New York.

The same idea, of the propulsion of vessels by means of spiral wheels, was afterwards suggested by Franklin, Watt, Paucton and others.

Previous to the year 1802, the screw propeller was twice distinctly patented in England; and the invention was described, in each patent, by a specification and drawing. The patent to William Lyttleton was granted in 1794; and his screw propeller is shown in the drawing annexed.

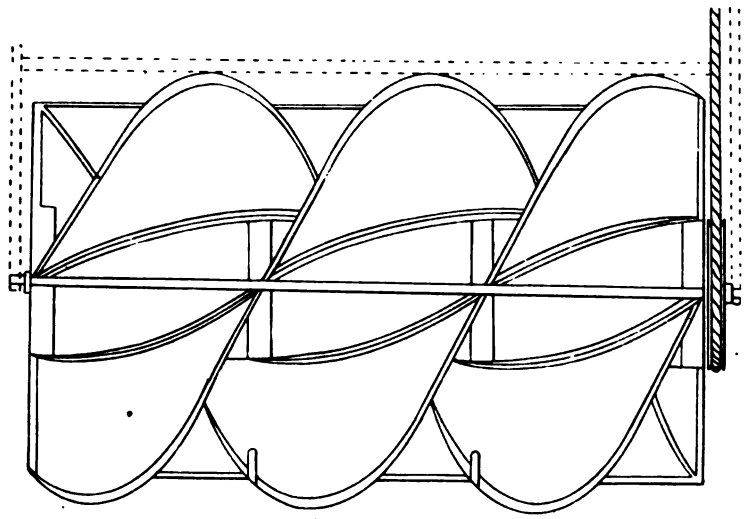


FIG. 2.

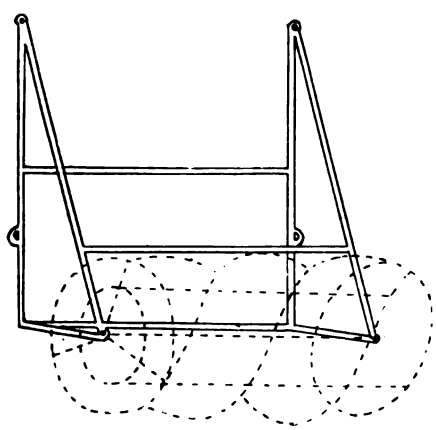


FIG. 3.

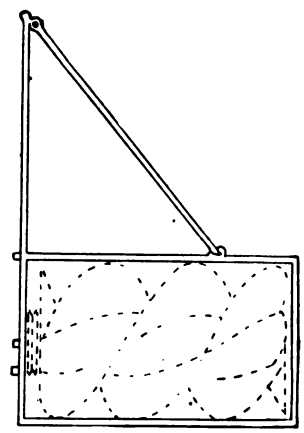


FIG. 4.

Lyttleton's Screw Propeller and devices for attaching it to the ship's sides, bow or stern.*

* Traced from his Patent Specifications No. 2000. A D. 1794, July 15.

This screw propeller, was a long spiral wheel, revolved by an endless rope on a pulley worked by manual labor. It was tried on a vessel at the Greenwich dock, London; and a speed of two miles an hour was said to have been attained. The second patent was granted to Edward Shorter in 1800. Shorter had two plans, one, Fig. 5, a form of duck-foot paddles, with an alternate movement, often proposed and tried, before and since; the other, Fig. 6, a two-bladed screw propeller, attached to an inclined shaft carried by a universal joint to the deck of the vessel. Both plans are shown in the annexed drawings. By one of Shorter's plans, but by which one is uncertain, the transport "Doncaster" was said to have been propelled at a speed of a mile and a half an hour, by eight men working at a capstan.

THE FIRST APPLICATION OF STEAM TO A SCREW PROPELLER WAS MADE BY JOHN STEVENS ON THE HUDSON RIVER IN THE YEAR 1802.

His experiments in screw propulsion commenced in 1801, and were continued until some time in the year 1806. The engines that he tried in 1802, 1803, and 1804, were all non-condensing; and the boilers were all multi-tubular, in which steam of a high pressure was maintained. His propeller was the short four-bladed screw propeller now in use.

THE SCREW PROPELLER OF 1802.

The following description of this boat is given by Colonel Stevens in a letter to the *Medical and Philosophical Journal* of New York, January 1812:

"To avoid the mischievous effects, necessarily resulting from "the alternating stroke of the engine of the ordinary construction, "I turned my attention to the construction of steam engines on the "rotary principle. And the first steamboat put in motion on the waters "of the Hudson, was one constructed on this principle. I trust, "then, I shall be pardoned, should I enter into a more minute de-"scription of this little curiosity than may at this time appear neces-"sary. For simplicity, lightness, and compactness, the engine far

"exceeded any I have yet seen. A cylinder of brass, about 8
"inches in diameter, and 4 inches long, was placed horizontally

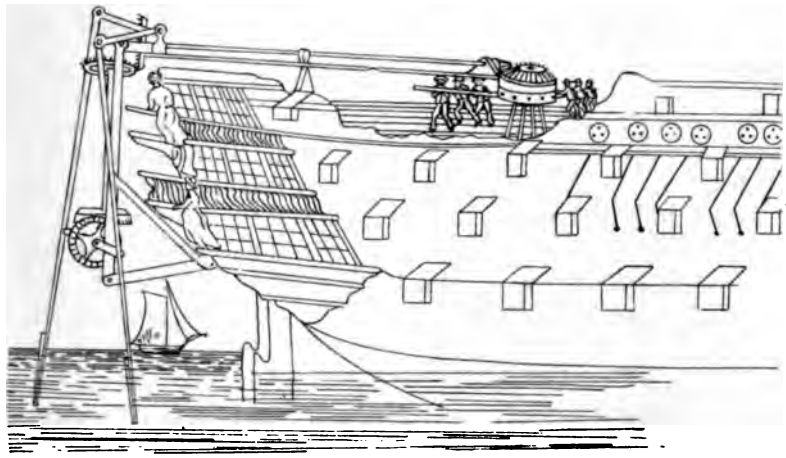


FIG. 5.

Shorter's Plan of Alternate Paddle Propulsion.*

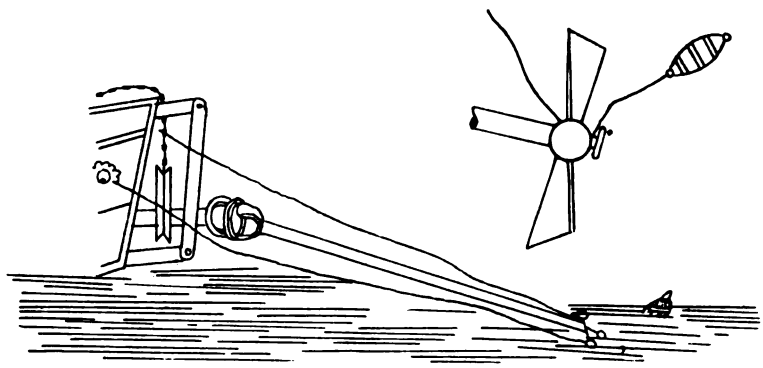


FIG. 6.

Shorter's Plan of Screw Propulsion.*

"on the bottom of the boat; and by the alternate pressure of the
"steam on two sliding wings, an axis passing through its center was
"made to revolve. On one end of this axis, which passed through

*Traced from his Patent Specification No. 274. A. D. 1800.

" the stern of the boat, wings, like those on the arms of a windmill, " were fixed, adjusted to the most advantageous angle for operating " on the water.

" This constituted the whole of the machinery. Working with " the elasticity of the steam merely, no condenser, no air pump was " necessary; and as there were no valves, no apparatus was required " for opening and shutting them. This simple little steam engine " was, in the summer of 1802, placed on board a flat-bottomed boat " I had built for the purpose. This boat was 25 feet long, and " about 5 or 6 feet wide. She was occasionally kept going until " the cold weather stopped us. When the engine was in the best " order, her velocity was about 4 miles an hour. I found it, how- " ever, impracticable, on so contracted a scale, to preserve due " tightness in the packing of the wings in the cylinder for any " length of time. This defect determined me to resort again to the " reciprocating engine."

THE SCREW PROPELLER OF 1803.

In relation to this propeller, Colonel Stevens, in the letter previously referred to, says:

" The unsuccessful experiment in which I had as above stated, " been engaged in conjunction with Chancellor Livingston and Mr. " Roosevelt, had taught me the indispensable necessity of guarding " against the injurious effects of partial pressure." (By this term, he alluded to the imperfect bracing between the cylinder and shaft.) " And accordingly I constructed an engine, although differ- " ing much from those described in the specifications of my patents, " yet so modified, as to embrace completely the principle stated " therein. During the winter, this small engine was set up in a " shop I then occupied at the Manhattan Works, and continued " occasionally in operation until spring, when it was placed on " board the above mentioned boat, and by means of bevel cog " wheels, it worked the axis and wings above mentioned and gave " the boats somewhat more velocity than the rotary engine. But " after having gone some time; in crossing the river, with my son " on board, the boiler, which was constructed of small tubes, " inserted at each end into metal heads, gave way so as to be " incapable of reparation."

THE TWIN-SCREW PROPELLER OF JOHN STEVENS OF 1804, NOW ON EXHIBITION AT THE FAIR AT CHICAGO.

The following account of the boat and engine of 1804, copied from an earlier American publication, is from "Stuart's Anecdotes of the Steam Engine," published in London in 1829; Vol. II., page 467.

"At last he had recourse to Watt's engine*, with a cylinder "4½ inches in diameter and a 9-inch stroke; the beam was "omitted; the boiler 2 feet long, 15 inches wide, 12 inches high, "consisted of 81 tubes each an inch in diameter; his boat was 25 "feet long and 5 feet wide. This was tried in May 1804, and had "a velocity of 4 miles an hour; after having made repeated trials "with her, his son undertook to cross from Hoboken to New York, "when unfortunately, as the boat nearly reached the wharf, the "steam pipe gave way, having been put on with soft solder. This "boiler being damaged, the next one was constructed with the "tubes placed vertically. The engine was kept going for a fort-"night or three weeks, the boat making excursions of 2 or 3 miles "up and down the river; for a short distance he could make it sail "at a rate of not less than 7 or 8 miles an hour."

The following extract, in relation to this twin-screw vessel, is from a paper by Dr. James Renwick, written in 1858, addressed to Frederick De Peyster, of New York, and read by the latter at a meeting of the New York Historical Society; and then published, in August of the same year, in the "Historical Magazine" No. 8, of Vol. II. Doctor Renwick was Professor of Natural and Experimental Philosophy in Columbia College, New York, for many years; and was the author of several treatises on the steam engine, among which was a much-quoted article "On the Steamboats of the United States of America," contributed to Tregold's "Treatise on the Steam Engine," published in London, 1838:

"The first time that I ever heard of an attempt to use steam for "propelling vessels, was from a classmate of mine who resided "during the summer months at Belleville, in New Jersey. He had, "in the summer of 1803, seen an experiment on the Passaic River,

* The reciprocating rotative engine.

FIG. 7.

Twin-Screw Engine and Boiler of Col. John Stevens, built in Hoboken, N. J., in 1804, as exhibited by The Hoboken Ferry Company at the Columbian Exhibition, in a boat recently built to represent the original boat which plied, by this machinery, in the harbor of New York with an average speed of 4 miles, sometimes increased to 7 or 8 miles per hour.

View taken looking toward the bow from near the stern, much foreshortened.

FIG. 8.

'win-Screw Engine and Boiler of Col. John Stevens, built in 1804, in boat now at nbian Exhibition.
'iew taken from near the bow looking toward the stern, much foreshortened.

"which he stated to have been directed by John Stevens of "Hoboken. According to his account, the propulsion was attempted "by forcing water by means of a pump from an aperture in the "stern of the vessel.

"From some vague indications, it would appear that the elder "Brunel, afterwards so distinguished in Europe, was in the em- "ployment of Mr. Stevens on this occasion. In the month of May, "1804, in company with the same young gentleman and another "classmate, now the distinguished missionary, John H. Hill, of "Athens, Greece, I went to walk in the Battery. As we entered the "gate from Broadway, we saw what we, in those days, considered a "crowd, running towards the river. On inquiring the cause, we "were informed that 'Jack Stevens* was going over to Hoboken in "a queer sort of a boat.' On reaching the bulkhead by which "the Battery was then bounded, we saw lying against it a vessel "about the size of a Whitehall rowboat, in which was a small engine, "but there was no visible means of propulsion. The vessel was "speedily under way, my late much valued friend, Commodore "Stevens, acting as cockswain; and I presume that the smutty- "looking personage who fulfilled the duties of engineer, fireman, "and crew, was his more practical brother, Robert L. Stevens.

"A few years since, at the last fair of the American Institute, "held at Niblo's, I was asked to serve on a committee to report "upon a boat and engine, exhibited by the Messrs. Stevens; for the "purpose of sustaining the claim of their father to the honor of be- "ing the first inventor of the propeller. The circumstances I have "just recounted, had taken so strong a hold on my memory, that I "at once recognized the engine exhibited as that which I had seen "at the Battery nearly fifty years before.

"In respect to the propeller I could say nothing. One of my "colleagues on the committee, however, Mr. Curtis, at that time "United States Inspector of Steamboats for the port of New York, "recognized, as distinctly as I had done, the engine, the propeller, "which he had seen in the hands of the workmen by whom it was "manufactured. The dates corresponded, the apparatus was avowedly "making for Stevens of Hoboken. Thus it happened, that an "accidental choice had placed upon the committee, two persons

*John Cox Stevens.

" who were, by the union of their testimony, capable of establishing " the fact into the truth of which they were directed to inquire."

In relation to this twin-screw propeller, Dr. Thomas P. Jones, Superintendent of the United States Patent Office up to the date of its reorganization under the law of 1836, at which date Commissioners were substituted for Superintendents, says, in the *Journal of the Franklin Institute* for 1838, page 38:

"The late Colonel Stevens of Hoboken (near) New York, in " the year 1805, informed the writer that he had tried such wheels " in the stern of a boat, first using a single wheel in the center. The " tendency of the boat so tried, was to move in a circle; a result " due to the lessened resistance, as the vanes rose towards the sur- " face, in consequence of the greater ease with which the water was " removed out of the way. Subsequently, two such wheels were " tried, side by side, revolving in reversed directions."

This tendency of a single-screw propeller to turn a vessel is also mentioned in Colonel Stevens' letter to Doctor Hare, given below, and is now well recognized; a right-handed screw turning the bow of the vessel to port and a left-handed one to the starboard.

In the year 1844, by the direction of the sons of Colonel Stevens, this twin-screw engine and its boiler were overhauled by Mr. Isaac Dripps, then General Superintendent of Machinery on the Camden and Amboy Railroad, and afterwards in the same position on the Pennsylvania Railroad. The directions to Mr. Dripps were to make no alterations or additions except in minor parts where worn.

The defects of the soldered pipes and joints were then remedied. The parts added in 1844 are shown on the machinery, colored yellow.

As the original boat had decayed in 1844, a new one was then built to receive the engine; and the boat with the engine then in it, was exhibited at the fair held at Niblo's Garden, Broadway and Prince Street, New York, in October 1844, and tried on the Hudson River, where it attained a velocity of 8 miles an hour.

"AMERICAN INSTITUTE
NEW YORK, April 7., 1893.

"*Francis B. Stevens, Esq.*

"DEAR SIR: You ask me to give my recollections of the pro-"peller boat of Colonel Stevens of Hoboken, N. J. exhibited by "his sons at the Exhibition of the American Institute held in Niblo's "Garden in 1844; although so many years have elapsed, it is as "fresh in my memory as if it occurred yesterday.

"The boat was about the size of our Whitehall boats, and had a "rod on each side extending to the stern on which was attached pro-"pellers.

"A supplemental report of the invention of Mr. Stevens for that "year 1844 is now in the Archives of the American Institute, the "report was made by Gen. Thomas W. Harvey the Chairman of the "Committee of Judges.

"Yours respectfully,
JOHN W. CHAMBERS,
"Fifty-eight years with the American Institute."

Extract from "Supplementary Report of the Judges Appointed on Steam Engines, Etc., Seventeenth Annual Fair of the American Institute":

"The execution of its work shows the age of infancy in "mechanical construction in this country and on this account it is a "*gem;* it equally shows the marks of ripe intellect and skillful "adaptation to the object sought to be attained, still unsurpassed "by present maturity.

"In reverting back to the time of its construction we can dis-"cover the cause why this masterly conception was laid up as use-"less, at that time. * * *

"Respectfully submitted by your Committee.

"New York October 18, 1844.

"Signed: THOMAS W. HARVEY,
"GEORGE N. MINES."

The twin-screw engine and its boilers are now in exactly the same condition as when exhibited in 1844. They were preserved in the Stevens Institute at Hoboken, N. J. until a few years ago,

when they were transferred to the Smithsonian Institution at Washington.

As the boat built in 1844 has also decayed, a third boat, of the same size has been lately built, and the twin-screw engine has been placed in it.

DESCRIPTION OF THE TWIN-SCREW ENGINE.

Different photographic illustrations of the engine, etc., its boiler, and also of this machinery placed in the boat lately constructed of the size of the original boat of 1804, are shown in Figs. 1, 7, 8 and 9.

Colonel Stevens' plan for working twin screws by a single cylinder is the most simple one that could be devised. The reaction of the connecting rods against each other at their junction with the piston-rod acting as a parallel motion, or as slides would do, to keep the rod in alignment. When the screw propeller came into use, after a lapse of nearly forty years, this plan of a single cylinder for twin screws was revived in this country and abroad, being known in France as the "Etoile Engine." The valves on this twin-screw engine are formed by two-way cocks, a modification of the single-way cocks used by Savery and Newcomen, one cock at each end of the cylinder, answering both for the admission and the exhaust of steam.

The valve motion is derived from a crank on the inboard end of one of the propeller shafts. This crank works a rack, the teeth of which mesh into those of wheels on the plugs of the two-way cocks; this motion being similar to the toothed rack and segment of a wheel which Watt used, in one of his first engines, to raise his conical valves.

The boiler is one form of the multi-tubular boiler of Colonel Stevens. It has 28 copper tubes, each 1½ inches in diameter and 18 inches long, 14 tubes projecting from each side of a rectangular chest. The grate is placed at the end of one set of tubes, and the

flame passes around these tubes and then under the chest and around the tubes at the other end to the smokestack.

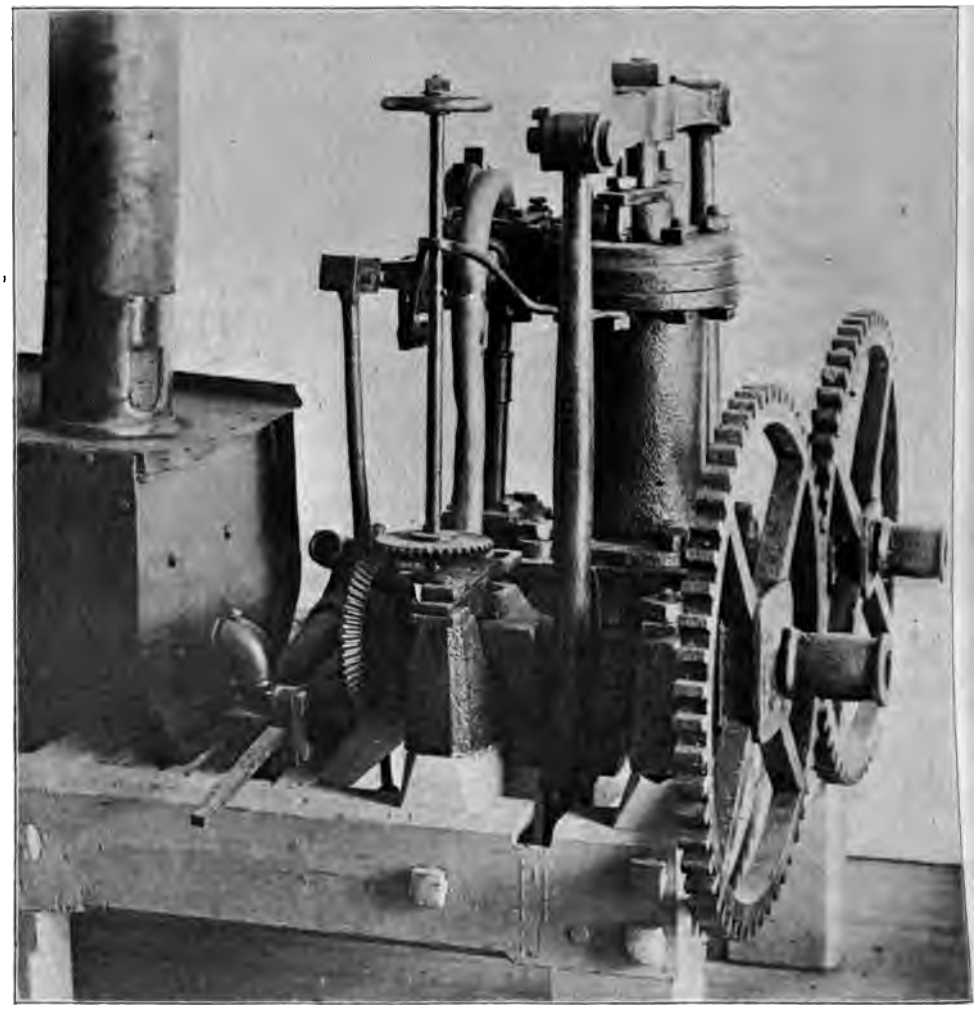


FIG. 4.

The following letter in relation to his screw propellers was written by Colonel Stevens to the well-known scientist, Dr. Robert Hare, of Philadelphia:

"HOBOKEN, Nov'r 16th., 1805.

"DEAR SIR:

"I have received your favor of the 8th inst. communicating an "outline of Mr. Weeden's contrivance for propelling boats. The "attention you have manifested on this occasion merits my warmest "acknowledgments, as it evinces the interest you feel in the suc- "cess of my project. But although I am persuaded I should "derive no advantage from Mr. Weeden's contrivance, yet I shall "ever preserve a due estimation of your kind intentions.

"With the surprising effects of the Chinese scull, I have long "been acquainted." (He alludes to a mill wheel, then called the tub wheel, the Chinese scull or the flutter wheel: one form of which, developed afterward, is the turbine.) "And it is now five "or six years ago that I made an attempt to apply a steam engine, "the construction of which was admirably adapted to the purpose, "to working a system of sculls attached to the stern of a boat—but "failed of success from the inefficiency of the power in the engine "I employed owing principally to the imperfection of the boiler. "But, my dear sir, I am fully satisfied, both from theory and prac- "tice, that my present mode of applying the power of a steam "engine to propelling boats is in various respects preferable to any "possible adaptation to the purpose, of this scull with an alternate "movement.

"You may recollect the description I gave you when I first had "the pleasure of seeing you at Hoboken. To the extremity of an "axis passing nearly in a horizontal direction through the stern of "the boat, is fixed a number of arms with wings like those of a "windmill or smoke jack. These arms, are made capable of ready "adjustment, so as that the most advantageous obliquity of their "angle may be attained after a few trials. The principle of an "oblique stroke is the same here, as in the scull—but the continuity "of movement in the wings, gives them greatly the advantage over "the alternation in the sculls; both in the loss of time, and the re- "sistance of the fluid in the change of motion: besides that, this "change of motion must give to the boat a wriggling movement; "and it has also a tendency to elevate and depress the stern of the "boat. The sculls, would also be liable to be affected by the swells "in rough water, and, like the paddles I had some thoughts of "using, would be an awkward appendage to the stern of the boat.

"The consideration which determined me, when I saw you last, to "make a trial of the paddles, was merely to avoid the necessity of "giving the boat a draught of water too great for passing the over- "slough near Albany; but this objection to the use of wheels, I ex- "pect to obviate by an increase of the number of them, and conse- "quent dimunition of their diameter. Indeed, it is absolutely "necessary to have at least two, revolving in opposite directions, to "prevent the tendency to rotation which a single wheel gives to the "boat. Since you were here, I have made a fair experiment on the "wheel, compared with oars. Two men were placed at two cranks, "by which a wheel in the stern of the boat was turned; and with a "stop watch, the time of passing over a given distance was pre- "cisely ascertained. After making a sufficient number of trials, "the wheel was taken off and the same men were furnished with "oars. The result of repeated trials, was a few seconds in favor of "the wheel. It is unnecessary to observe, that the wheel must have "worked to much disadvantage. The proper angle of obliquity, "was not attended to; besides, the wings were made with a flat "surface; whereas, a certain degree of curvature was necessary. "And in order to give a due submersion to the wheel, the axis was "inclined at least 30 or 40 degrees below the horizontal line. The "machinery too, was put up in a very coarse manner.

"One very important consideration in favor of these wheels is "the facility with which they can be defended from all external "injury, by placing them in the stern thus:

FIG. 10.*

"My foreman promises me to have the engine agoing in the "boat in about two weeks from this time. I shall embrace the first "opportunity of acquainting you with the result of my experiments."

"I am dear sir with esteem and regard yours etc."

*The above figure is an exact reproduction of a tracing of the pen sketch in Colonel Stevens' letter.

FIG. 11.

Propeller Hub with Adjustable Blades, of 1804.

THE PROPELLER HUB AND BLADE.

These are now on exhibition at Chicago, and are shown in Fig. 11.

This hub and blade were brought into the District Court of New York at the April term in 1844, at the request of the counsel of Ericsson and of Hogg & Delamater, in the suit of J. B. Emerson of New Orleans, for the infringement of his patent in manufacturing the Ericsson propeller; and it was fully identified, as a portion of a screw propeller used on the Hudson River, by John Stevens. In this suit, Emerson claimed that his patent covered the form of Ericsson's propeller; and he also broadly claimed the use of the screw propeller. The evidence of the earlier use by Stevens of the blade exhibited in court, was perfect; and Emerson's broad claim was disallowed. The jury, however, awarded him damages for the infringement of the form of his screw propeller. The case was carried, on appeal, to the Circuit Court in 1847; and decided in the favor of Emerson by the Supreme Court at Washington in 1850.

This propeller blade, is made in accordance with the description given in the letter to Doctor Hare. The broken shank on the hub shows this propeller to have been, when last used, the short two-bladed screw propeller of the present day, with the blades separately attached; and the two other opposite holes in the hub show that it was made to be also used as a four-bladed propeller. The blades, are shown attached to the hub by a round bar or shank fitting into a corresponding hole in the hub, and with its axis perpendicular to that of the propeller shaft; so that the pitch can be adjusted by slightly turning the bar or shank in the hub. In his letter to Doctor Hare, Colonel Stevens says "These blades are made "capable of ready adjustment, so that the most advantageous "obliquity of their angle may be attained."

This method of adjustment is identical in principle with that of Griffiths', whose propeller, the automatic machinery for adjustment being omitted, is shown by Fig. 12.

Griffiths' plan for carrying into effect this method of adjustment is excellent. He first proved that by making the hub globular or partially globular it could be enlarged without detriment, to a

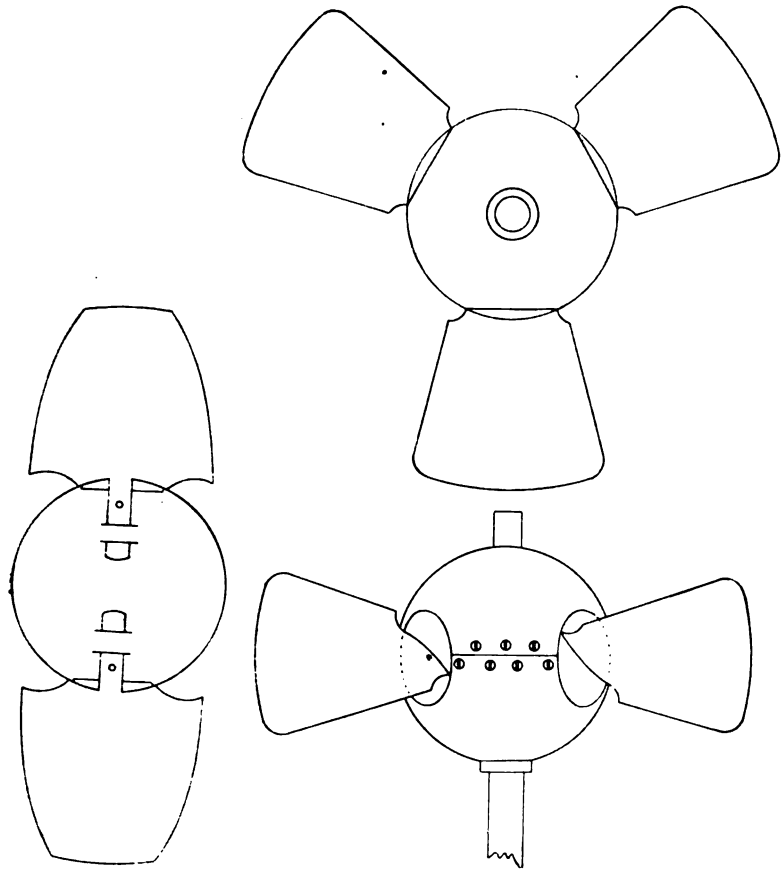


FIG. 12.

Griffiths' Screw Propeller.*

certain extent, beyond the size previously used; and, after he had discarded his automatic machinery, he utilized the hub, then only

*Traced from his patent Specification No. 12769. A. D. 1849, September 13.

partially enlarged, for the attachment of his blades to it, by forming a flange with a plane surface at the base of each blade, and by bolting this flange to a corresponding surface made on the hub. The adjustment of the pitch is made, at the present day, by slightly altering the bolt holes of the flange.

The improvement of Griffiths, is regarded by the writer as the greatest made on the form of the screw propeller since 1804.

THE PROPELLER BOATS OF 1805–6.

James Alexander Stevens, who was the third son of Colonel Stevens, and who was 16 years of age at the commencement of the year 1806, has described this boat as being about 50 feet long, and as drawing about 4 feet of water, and has stated that he was on it when it made several trial trips up the Hudson River. In this he was corroborated in a letter from his uncle-in-law, Horace Binney of Philadelphia, to whom he wrote in 1871, asking him if he remembered taking a trip on this vessel in 1805–6. Mr. Binney replied that he recollected it perfectly; mentioning that, on the return of the boat to the cove above Hoboken, some difficulty occurred in landing, on account of the draught of water of the boat. This boat is described in the letter of John Stevens to Doctor Hare as a twin-screw vessel, then nearly completed.* As it was a much larger vessel than the others, the defects of the machinery would have been much more manifest.

THE MULTI-TUBULAR BOILER OF JOHN STEVENS, USED ON HIS PROPELLERS.

John Stevens patented his multi-tubular boiler in this country on the 26th. of August, 1791, and the 11th. of August, 1803, and in England, May 31, 1805. In addition to the boiler exhibited, two more are described in Stuart's publication previously mentioned; one having 81 tubes each 1 inch in diameter, and the other having about 765 horizontal tubes each 1 inch in diameter and 2 feet long, placed between two tube sheets of cast brass, each sheet being 4x6

feet, the tubes being spaced 2 inches from center to center. The tube surface was 400 square feet. Another form of his boiler, with vertical iron tubes, that operated an experimental locomotive at Hoboken in 1825, is still preserved.

The English patent, of 1805, was taken out by John Cox Stevens, then a very young man, who described the subject of the patent, the multi-tubular boiler, as "an invention communicated to him by his father."

It was he whom Dr. Renwick recognized as coxswain of the "queer sort of a boat" at the Battery in May, 1804. In after years, he was the founder and first Commodore of the New York Yacht Club, and commanded the yacht "America" in her famous race off the Isle of Wight in 1851. When in England in 1805 he went to Heathfield, the seat of Watt, who had then retired from business, and presented a letter from his father. Watt received him kindly but reiterated his well-known objections to the use of steam at a pressure over two or three pounds above the atmosphere.

These boilers of Colonel Stevens have often been referred to in relation to the introduction of the multi-tubular boiler on locomotives.

WHAT COLONEL STEVENS ATTEMPTED, AND WHY HE FAILED.

At the date of the introduction into use of the screw propeller, the pressure of steam carried on the boilers of condensing engines of the vessels that now navigate the bays and rivers of the Atlantic seaboard, averaged about 30 pounds per square inch; while, on the innumerable steamboats on the Mississippi and its tributaries, the steam averaged 140 pounds per square inch. At the same date, the pressure on English vessels was the same that Watt had established—viz., 2½ to 3 pounds. The "Great Western," in 1838, carried that pressure, and the iron screw propeller, "Great Britain," in 1840, carried only 5 pounds per square inch.

Colonel Stevens attempted to introduce steam navigation by the screw propeller; laboring at the project for six years, and

relinquishing it only one year before the successful application of the paddle wheel by Fulton. The five distinct means he proposed were:

First. The short four-bladed screw propeller.

Second. The use of steam of high pressure.

Third. The multi-tubular boiler.

Fourth. The quick-moving engine connected directly to the propeller shaft.

Fifth. Twin screws.

None of these means were applied to steamships for forty years thereafter; and yet, all are elements in the success of ocean navigation at the present day.

Steam engine building, as a trade, did not exist in the United States until the year 1797; although it had long been established in England. Farey, in his "Treatise on the Steam Engine," London, 1827, states that in the 62 years, intervening between Newcomen's first engine in 1712, and Watt's first engine in 1774, the steam engine had been extensively introduced throughout England, in the form of pumping engines for draining mines, and for raising water to turn overshot wheels, by which cotton mills and a great variety of machinery were driven; and that as early as 1750, steam engine building had become a recognized trade in England.

The exportation from England, of all machinery, was prohibited by law, except upon an order from the King in Council, until 1820, when the law was repealed. Three known instances when this order was obtained, were, for the pumping engine at Chantilly, for supplying the city of Paris with water; for the pumping engine of the Manhattan Company, for supplying the city of New York in 1799; and for Fulton's rotative engine, in 1806. All three engines were made by Watt.

Towards the close of the last century, Hornblower, a distinguished English engineer, came to this country, and erected a pumping engine at the mouth of the shaft of a copper mine near Belleville, on the left side of the Passaic River, New Jersey, about 8 miles

from New York; and established a small machine shop near by. This, was then the only machine shop in the country. The second, was erected in 1801, by McQueen, in Duane Street, New York, near the Manhattan pumping engine.

The efficiency of the tools for engine building, in this country, in the year 1800, can be judged, by the following extracts from a letter written by P. T. Cope to the city authorities at Philadelphia, in relation to the boring of a cylinder 38½ inches diameter by 6 feet stroke, for the pumping engine that was erected in the square at Broad and Market Streets, now the site of the Municipal Building. This letter, dated July 3, 1800, from Belleville, was published in the *Scientific American* Supplement No. 45, November, 1876, page 706. He says that the boring of the cylinder was commenced on the 9th. of the previous April; that the boring had been in progress from that date to the date of the letter, July 3d., two men working day and night, relieving each other, "one almost living in the cylinder"; and that he expected "that about six weeks would be required to finish it."

An inspection of the rude workmanship of the twin-screw engine, as well as that of the boiler, will explain the reason for the abandonment, by Colonel Stevens, of his plan of screw propulsion. There were no tools or competent workmen in America at that date to properly construct the steam engines and the boilers that he planned between 1800 and 1806. Success was impossible.

When he finally realized this, unwearied by his attempts to introduce steam navigation, dating from the year 1791, he reverted to the paddle wheel, with its slow-moving engine, and with the boilers then in use, carrying steam at the pressure of 2 or 3 pounds above the atmosphere. He was engaged in building the "Phoenix" when Fulton arrived from Europe with the engine made for him by Watt in 1806, which, complete in all its details, and in these respects, far in advance of any engine that could then have been built in this country, achieved success.

Fulton's engine was the first rotative steam engine that was allowed to be exported from England.

The paddle steamboat "Phoenix" was completed a few weeks after Fulton's vessel; and, as she was debarred from navigating the waters of the Hudson by the monopoly given to Fulton by the Legislature of the State of New York, she was sent by sea to Philadelphia. The "Phoenix" was the first steamboat that navigated the ocean.

Colonel Stevens always maintained, that with proper machinery the screw would be found superior to the paddle for sea-going vessels. In 1816, he presented a plan to our Government for a man-of-war propelled by a screw. This may still remain in the archives of the Government at Washington.

In regard to the claim in behalf of Fulton, for the introduction of steam navigation, no one has admitted the justice of that claim more unqualifiedly than his unsuccessful rival. Fulton's fame, rests not merely upon the success of the "Clermont" in 1807; but upon what he accomplished, in the interval between that date, and that of his death in 1814. Colonel Stevens, in the letter to the Medical and Philosophical Society, previously quoted, says:

"It is an unquestionable fact, that he" (Fulton) "was the "person who for any practical useful purpose, applied water wheels "on each side of a steamboat." And again

"Fulton, has, however, incontestably the merit of being the "first person who applied steamboats to useful purposes."

THE INTRODUCTION OF THE SCREW PROPELLER INTO USE.

This was done simultaneously by Smith in England, and by Ericsson in the United States.

Both were men of great ability. Each considered himself the inventor of the screw propeller. Each took out patents in England, in 1836, and in the United States, two or three years afterwards. Each patent differed radically from the other; neither patent, for the general application of the screw propeller, was sustained, either

here or abroad; and neither Smith nor Ericsson patented additional improvements on the screw propeller.

Each built small screw vessels, in England, that were successfully tried in 1837; Smith's being of six tons burthen, with a wooden screw, driven by a six horse-power engine, and Ericsson's, named the "Francis B. Ogden," having about double the tonnage and power.

Each built larger screw vessels that were successfully tried in England in 1839. Smith's vessel, the "Archimedes," being upwards of 200 tons burthen, and driven by engines designed by Rennie, of 90 horse-power, circumnavigated the island of Great Britain in May, 1840. Ericsson's vessel, the "Robert F. Stockton," smaller, and with less power, was tried in England under steam, and then, in April, 1839, crossed the Atlantic under sail.

Each introduced the screw propeller on merchant vessels in 1840.

Each introduced the screw propeller on war vessels in 1843. Ericsson, on the "Princeton," and Smith, on the "Rattler."

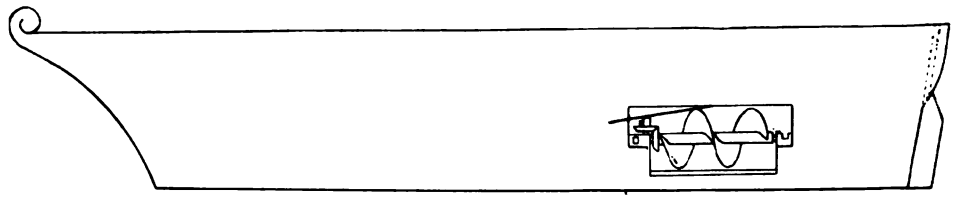
Both were materially assisted in the introduction of the screw propeller into use, by the improvements of those who built screw propeller vessels independently of the patents of either.

The plan of Ericsson's screw propeller on the "Robert F. Stockton" was in exact accordance with his patent. Smith's plan on the "Archimedes" varied essentially from his patent.

Both finally modified their screw propellers, as patented, into the short screw propellers now in common use.

By the annexed drawing, traced from that of Smith's patent, his screw is shown with one long blade modeled after the screw of "Archimedes," a screw for lifting water, that differs radically in its action from the screw propeller. The length of the blade, measured longitudinally on the hub, is shown on his drawing to be sixteen times greater, in proportion to the diameter of the screw, than that of the "Rattler," in 1843.

This long single-bladed screw is shown placed far under the vessel's stern, while on the "Rattler," in 1843, it is shown placed in



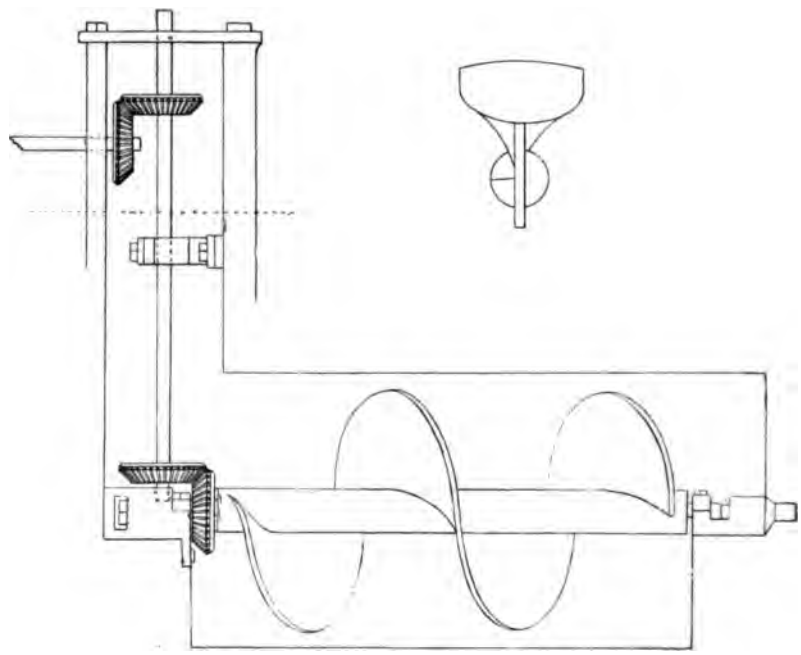


FIG. 13.
F. P. Smith's Screw Propeller.*

the clear water, and in the position shown in the annexed drawing of Cummerow's propeller, in his patent of 1828. Smith's method of

*Traced from his Specification, A. D. 1836, May 31. No. 7104.

connecting his screw to his engine by a vertical shaft, placed in a water-tight well, is an absurdity, equaled by his statement that his screw may be made of wood, of which material his screw was actually made, for the boat driven by a six horse-power engine in 1837.

Smith had great business ability, judgment and perseverance. Assisted by his friends, he organized the Ship Propeller Company; chartered by Parliament, in 1839, and, backed throughout by this company and by the English Admiralty, he introduced the screw propeller in England.

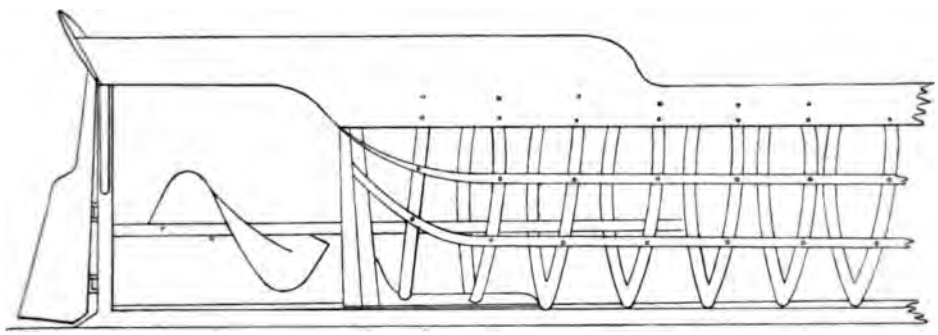


FIG. 14.

Cummerow's Propeller.*

Ericsson's screw is shown in its well-known form, Fig. 15, placed in the clear water of the run, and with its two shafts one inside of the other. His patent drawing shows each of these shafts terminating in a separate crank; this not being copied in the tracing, for want of space.

The writer examined the machinery of the "Robert F. Stockton," a few days after her arrival in the Hudson River, in May, 1839; and, a few days after that, he examined the two propellers, one being right-handed, and the other left-handed, on the wharf at Bordentown, New Jersey.

*Traced from his Specification, A. D. 1828, December 10. No. 5730.

Both machinery and screw corresponded with the annexed drawing of the patent taken out three years previously. When tried on the Delaware River, the vessel was found unmanageable

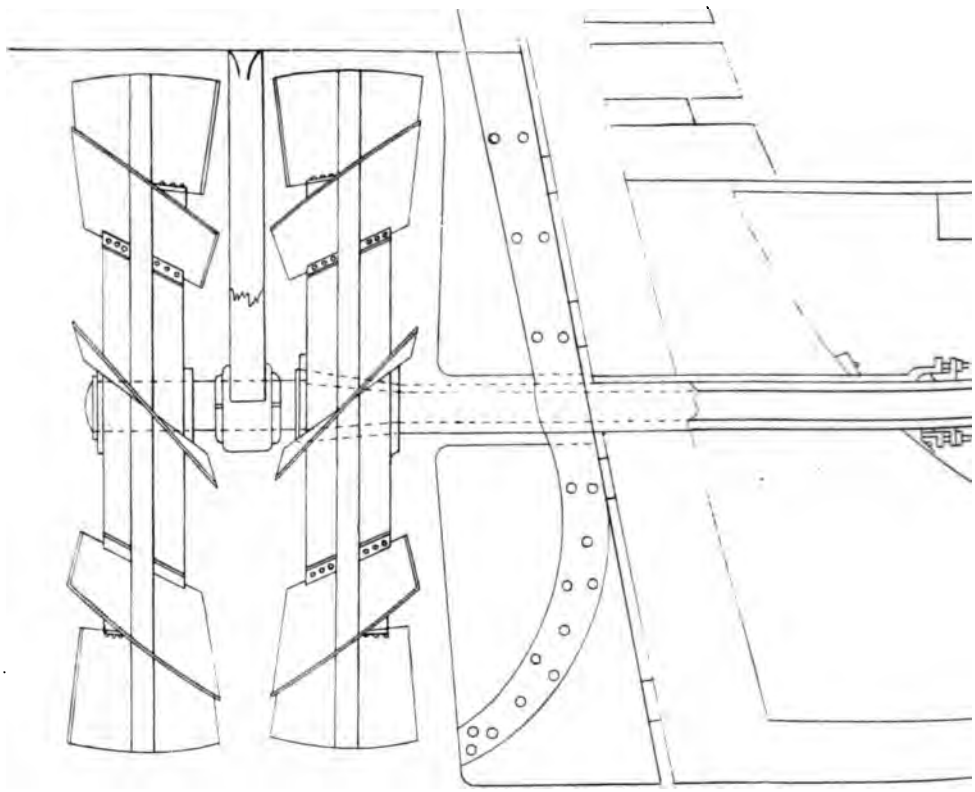


FIG. 15.

Ericsson's Screw Propeller.*

under steam, and the position of her rudder was changed to that shown in Cummerow's patent, and the second screw was discarded. Thus altered, with her name changed by Commodore Stockton to the "New Jersey," she remained in service for 30 years. The defects of Ericsson's plan were, the unnecessary complication of the

* Traced from his Specification, A. D. 1836, July 13. No. 7149.

two screws, the one placed behind the other, and having its shaft running through the shaft of the other,—the small size of his rudder, and its position ahead of the screw, and in that position much too close to it;—lastly, the form of his propeller, with its blades attached to a cylinder, which, though fairly effective, is inferior to the ordinary screw now in use.

Bourne, in his "Treatise on the Screw Propeller," published in England in 1852, says: "Probably the exertions of either" (Smith or Ericsson) "would have sufficed to introduce the screw into "practical operation."

The writer ventures the opinion, that the screw propeller would have certainly been introduced into practical operation in both, England and this country, in the decade between 1836 and 1846, independently of the exertions of either Ericsson or Smith, for the following reasons: Prior to 1836, when their patents were taken out, the subject of crossing the Atlantic by steam had been widely discussed on both sides of the ocean, and steps had been taken for regular communication across the ocean by the paddle.

This was effected in 1838 by the "Great Western"; but the defects of the paddle for ocean navigation were, then, as now, generally admitted. The accounts of the different screw propellers, that had been tried at different times, previous to 1836, had been widely published, both here and abroad; and the substitution of the screw for the paddle wheel, had been many times proposed. In the seven years previous to the patents of Ericsson and Smith in 1836, eleven patents for the screw propeller were taken out in the United States; the plans of three of which—viz., the patent of B. M. Smith, in 1829, for twin screws; that to Josiah Copely, in 1830, for a close approximation to the short screw propeller now in use; and that to J. B. Emerson, for a single wheel, on Ericsson's plan, in 1834; were superior to the wheels, as they were patented in 1836, of either Smith or Ericsson.

The patent records of the United States show, that up to the present time, more than two hundred patents have been taken out for

various forms of screw propellers, which embody the general principle of the rotation of blades, having their surfaces placed obliquely to the axis of the shaft that turns them: this shaft being placed parallel or nearly so, to the keel. These forms, are varied in almost every conceivable manner; many whimsical, and even grotesque: and, yet, any one of them will propel a vessel. In the year 1840, the United States was well prepared for the introduction of the screw propeller; having then, an abundance of machine shops, good tools, and excellent machinists; and the first trial of a screw propeller, of almost any form, driven by a steam engine, and placed on a vessel fit for commercial purposes, must then have led to the introduction of screw propulsion.

COMPARISON OF THE POWER OBTAINABLE FROM LIQUEFIED CARBONIC ACID GAS AND FROM COMPRESSED AIR.

BY PROF. D. S. JACOBUS.

IN a recent investigation, it was necessary to determine the work developed by expanding carbonic acid gas, and to compare it with that obtainable from compressed air. To determine the work developed by the carbonic acid, Zeuner's equation was employed. As the constants for Zeuner's equation had not been worked out for carbonic acid, except in a saturated condition, it was necessary to determine their value for superheated gas. Making use of Regnault's values for the product of the pressure and volume of

carbonic acid at various temperatures, we have the following values for the B, C and n in Zeuner's equation, $p\,v = B\,T - C\,p^n$:

	Superheated Carbonic Acid.		Saturated Carbonic Acid.
	$p = 2\,p'_0$.	$p = 7\,p'_0$.	
B	35.45	35.45	35.14
C	5.90	2.35	.248
n	.51	.63	.888

p'_0 is about one atmosphere. The constants for the saturated gas are reduced from those given in Zeuner's work.*

It is evident, from this table, that the gas does not follow Zeuner's law very closely; or, in other words, that C and n are not constants.

The values employed in the calculations are those for

$$\frac{p}{p'_0} = 7.$$

The results of the calculations show that, for a given tank capacity and carbonic acid and air stored at the same pressure, the (liquefied) carbonic acid is capable of developing four to five times more power than compressed air. If a compound engine is employed, and the gas or air is heated so that the temperature at the beginning of expansion is 383.5° Fahr., the carbonic acid engine requires 21.6 pounds of carbonic acid per hour per horse-power, and the air engine 14.3 pounds of air. On this basis of 21.6 pounds of carbonic acid per hour per horse-power, we can determine the price it would have to be sold at to be an economical power.

If the carbonic acid is exhausted into the atmosphere, the cost is much too great for ordinary power purposes. If the exhaust is condensed, the engine will have the same theoretical efficiency as an engine using any other vapor through the same range of temperature, and the working pressures will be very high, so that practical difficulties are met with. Experiments with carbonic acid gas

* *Zeuner's Technische Thermodynamik*, Vol. II., p. 273.

engines, in which the exhaust is condensed, have verified the conclusions pointed out by theory.

The calculations for the above table, and for the work developed per pound of vapor, are given in the Appendix.

APPENDIX.

ZEUNER'S EQUATION WHEN $\frac{p}{p'_0} = 2.003$.

THE density of carbonic acid at atmospheric pressure and 32° Fahr. is 1.529, and its co-efficient of dilatation .002067. To find the value of B in Zeuner's equation

$$p\,v = B\,T - C p^n \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

we have

$$B = 2117\, v_0\, \alpha \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

in which α is the co-efficient of dilatation.*

The weight of one cubic foot of air at 32° Fahr. and atmospheric pressure is .08073 pounds; hence we have

$$B = \frac{2117 \times .002067}{.08073 \times 1.529} = 35.45.$$

Regnault's experiments on the product of the pressure and volume of carbonic acid gas were made at 7.7° C., or 45.86° Fahr.†

If we designate the volume of one pound of carbonic acid, at the temperature at which Regnault's experiments were made, and at atmospheric pressure by v'_0 we have

$$v'_0 = \frac{1}{.08073 \times 1.529}\,(1 + .002067 \times 13.86) = 8.333 \text{ cu. ft.},$$

and, as the pressure of one atmosphere is equal to 2117 pounds per square foot,

$$p_0\, v'_0 = 8.333 \times 2117 = 17641.$$

The initial pressure in Regnault's experiments on carbonic acid was 774.03 m.m. The product $p_0\, v'_0$ is for the pressure of 760

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* $\alpha = \frac{d\,v}{v_0 d\,T}$. See p. 100, revised edition "Ice-Making Machines," by M. Ledoux. Van Nostrand's Science Series.

† For experiments quoted see Experiénces par M. V. Regnault, Vol. II., p. 260.

m.m. Taking the rate of variation of $p\ v$ the same as that which occurs over the interval from 774.03 to 1045.29, which is the next reading in Regnault's table, we have as the ratio for this range*

$$\frac{p'_0\ v'_0}{p_1\ v_1} = \frac{148219}{147728} = 1.00332$$

The ratio between the values of $p\ v$ at 760 and at 774.03 m.m. is

$$1 + \frac{774.03 - 760}{1045.29 - 774.03} \times .00332 = 1.000172$$

$$p'_0\ v'_0 = p_0\ v'_0 \div 1.000172$$

$$= 17641 \div 1.000172 = 17638.$$

If $p\ v$ be a similar product for $p = 2.003\ p'_0$, we have from Regnault's experiments,†

$$p\ v = 17638 \div 1.00722 = 17512.$$

We have $p'_0\ v'_0 = B\ T - C\ p_0{}^n$,

and $p\ v = B\ T - C\ p^n$.

From which

$$\left(\frac{p}{p'_0}\right)^n = \frac{p\ v - B\ T}{p'_0\ v'_0 - B\ T} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Substituting the numerical values in this equation, we have

$$(2.003)^n = \frac{17512 - 35.45 \times 505.9}{17638 - 35.45 \times 505.9}$$

From which we deduce $n = .51$.

To determine C we have

$$C = (B\ T - p_0\ v'_0) \div p_0{}^n \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

$$= (35.45 \times 505.9 - 17641) \div 2117^n.$$

$$C = 5.90.$$

ZEUNER'S EQUATION WHEN $\frac{p}{p'_0} = 7.041$.

The pressures given by Regnault‡ are

$p = 5449.66$, and $p'_0 = 774.03$; hence $\frac{p}{p'_0} = 7.041$.

For this ratio of pressure Regnault gives

$$\frac{p'_0\ v'_0}{p\ v} = \frac{148219}{142171} = 1.0425.$$

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* Experiénces par M. V. Regnault, Vol. II., p. 236.

† Experiénces par M. V. Regnault, Vol. II., p. 260.

‡ Experiénces par M. V. Regnault, Vol. II., p. 236.

The temperature at which this experiment was made is not given in connection with it, but by comparison with a later portion of the work it may be supplied. This temperature, which is the one that has already been employed in determining the constants for Zeuner's equation for $p_1 \div p_0 = 2.003$, is given as 7.70° C., or 45.86° Fahr. A considerable variation in this temperature will effect the final result but little.

We have as before

$$B = 35.45$$

$$\text{and } p'_0\, v'_0 = 17638;$$

$$p\, v = 17638 \div 1.0425 = 16919.$$

By equation (3):

$$7.041^n = \frac{16919 - 17934}{17638 - 17934}$$

From which $n = .63$.

By equation (4)

$$C \doteq (17934 - 17641) \div 2117^{.63}$$

$$C = 2.35.$$

WORK DONE BY ONE POUND OF LIQUEFIED CARBONIC ACID GAS IN EXPANDING THROUGH A COMPOUND ENGINE.

We will assume that the liquefied carbonic acid gas is stored at a temperature of 68° Fahr. The initial pressure in this case is 864 pounds absolute per square inch. On, or before, entering the high-pressure cylinder, it is superheated, so that the temperature of the exhaust is 68 degrees. The gas is again heated on its entrance to the low-pressure cylinder, in order that the exhaust shall also be 68° Fahr. on leaving this cylinder. If the pressures be designated by p p_1 and p_2 we have

$$\frac{p}{p_1} = \frac{p_1}{p_2}$$

$$\text{or } p_1 = \sqrt{p\, p_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

We have $p = 864$ pounds per square inch.

$p_2 = 14.7$ pounds per square inch.

Therefore from equation (6) we have for the receiver pressure,

$p_1 = 112.7$ pounds per square inch.

Let T_1 = absolute temperature at beginning of expansion.

Let T_2 = absolute temperature at end of expansion.

c_p = specific heat of carbonic acid gas at constant pressure, which is .20 for the range of temperature considered.

C = Constant for Zeuner's equation = 2.35

B = Constant for Zeuner's equation = 35.45

n = Constant for Zeuner's equation = .63

A = Reciprocal of Joule's equivalent = $\frac{1}{772}$

Then we have*

$$T_1 = T_2 \left(\frac{p}{p_1}\right) \frac{A\,B}{c} \quad \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The work of compression in foot-pounds per pound, including the work of ejection of the gas, will be

$$\frac{c_p}{A}(T_1 - T_2) - \frac{Cp_2^{\,n}}{n}\left\{\left(\frac{T_1}{T_2}\right)^{\frac{n\,c_p}{A\,B}} - 1\right\} \ldots\ldots\ldots (8)$$

By substitution we have

$$\frac{A\,B}{c_p} = .23 \text{ and } \frac{n\,c_p}{A\,B} = 2.744.$$

The temperature as the beginning of expansion will be

$$T_1 = T_2 \left(\frac{p_1}{p_2}\right)^{.23} = (460 + 68)\left(\frac{112.7}{14.7}\right)^{.23} = 843.5$$

$$t_1 = 843.5 - 460 = 383.5^\circ \text{ Fahr.}$$

The work developed in the high-pressure cylinder per pound of carbonic acid will be

$$772 \times .2\,(383.5 - 68) - \frac{2.35\,(112.7 \times 144)^{.63}}{.63}\left\{\left(\frac{843.5}{528}\right)^{2.744} - 1\right\}$$

which reduces to

$$48713 - 4383 = 44330 \text{ foot-pounds.}$$

The work developed in the low-pressure cylinder will be

$$772 \times .2\,(383.5 - 68) - \frac{2.35\,(14.7 \times 144)^{.63}}{.63}\left\{\left(\frac{843.5}{528}\right)^{2.744} - 1\right\}$$

*See "Ice-Making Machines," by M. Ledoux. Revised edition, Van Nostrand's Science Series, pages 110 and 113.

which reduces to

$$48713 - 1215 = 47498 \text{ foot-pounds.}$$

The total work per pound of carbonic acid will, therefore, be $44330 + 47498 = 91828$ foot-pounds. One horse-power per hour is equivalent to 1980000 foot-pounds; hence, the weight of carbonic acid required per hour per horse-power is

$$1980000. \div 91828 = 21.6 \text{ pounds.}$$

WORK DEVELOPED BY COMPRESSED AIR IN EXPANDING FROM THE SAME INITIAL TEMPERATURES AND PRESSURES.

If air is used instead of carbonic acid the final temperature will be

$$T_2 = (383.5 + 460) \div \left(\frac{112.7}{14.7}\right)^{.29} = 467.2$$

The work per pound in both the high and low-pressure cylinders will be

$$772 \times .238\,(843.5 - 467.2) = 69140 \text{ foot-pounds,}$$

so that the work developed per pound of air will be

$$69140 \times 2 = 138280 \text{ foot-pounds.}$$

The weight of air per hour per horse-power will be

$$1980000 \div 138280 = 14.3 \text{ pounds.}$$

RELATIVE WORK DEVELOPED BY CARBONIC ACID AND COMPRESSED AIR PER CUBIC FOOT OF TANK CAPACITY.

The density of liquefied carbonic acid at various temperatures is as follows:*

Degrees Fahrenheit.	Density.	Weight per Cubic Foot.
32	.923	57.6
50	.852	53.2
68	.755	47.1
86	.549	34.3

* Reduced from experiments of Ad. Blümcke, *Physik und Chemie*, 1888, p. 10.

Messrs. Cailletet and Mathias give a table of densities that agrees very well with the work of Blümcke; and, in addition, state that the density at the critical temperature, or 87° Fahr., is .46.*

If a tank contains enough carbonic acid to be completely filled with liquid, at the critical temperature, the carbonic acid stored per cubic foot of capacity is

$$62.4 \times .46 = 28.7 \text{ pounds.}$$

The available power, when worked through a compound engine will therefore be

$$28.7 \times 91828 = 2635000 \text{ foot-pounds.}$$

In the case of compressed air stored at the same pressure, or 864 pounds absolute per square inch, and at the same temperature, the weight per cubic foot of tank capacity is

$$\frac{864}{14.7} \times .0726 = 4.27 \text{ pounds.}$$

The available work per cubic foot of tank capacity, when worked in a compound engine through the cycle already described, will be

$$4.27 \times 138280 = 590500 \text{ foot-pounds.}$$

The available work with carbonic acid, when worked through a compound engine, will therefore be about 4.5 times as great, for a given tank capacity, as is obtainable from air stored at the same pressure and temperature. Similar calculations to the above were made, assuming that direct expansion was employed in a single cylinder, and the ratio of the work done with carbonic acid and air was about the same as in the case of the compound engine.

* *Journal de Physique*, 1886, p. 560.

ECONOMIC POINT OF CUT-OFF IN A SPECIAL CASE OF AIR PROPULSION.

BY F. M. LEAVITT, M. E., '75.

THE propelling power of the Whitehead Automobile Torpedo is air compressed to 90 atmospheres. It is applied by means of an engine of ordinary type, to which air is admitted through a reducing valve.

This valve may be so adjusted as to maintain any desired uniform initial pressure on the engine, throughout the run, irrespective of the diminution of pressure in the reservoir, until that pressure is reduced to the pressure at which the valve is set. From this point, if the run be continued, the engine receives air at a constantly reducing initial pressure.

It is desirable, for various reasons, that the torpedo, in its flight, should maintain a constant speed; which speed, should be the maximum obtainable with the energy stored.

The problem which it is the object of this paper to discuss, is the determination of the proper point of cut-off of admission to the engine, which will give the highest efficiency. At first sight, it would appear that, there being no loss from cylinder condensation, as where steam is used, the highest efficiency would be attained with the shortest practicable cut-off, the limit being the point at which excessive expansion would cause freezing. A little consideration, however, shows this not to be the case.

It will be seen that in order to maintain a constant speed, and, at the same time, utilize as much as possible of the energy stored, the regulators should be so adjusted that the reservoir pressure, which decreases as the torpedo proceeds in its flight, should just fall, at the end of the run, to the pressure which has been maintained on the engine. In other words, the power must be kept constant, but the greatest possible volume of air must be used consistantly with this.

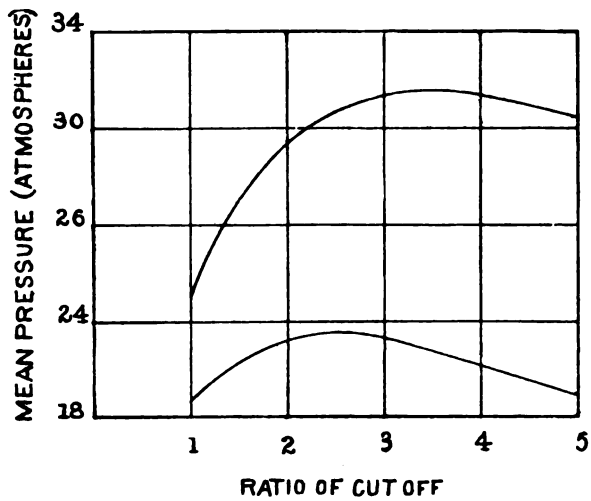
If p = initial pressure in engine, P and V = initial pressure and volume, respectively, in reservoir, U = volume swept through by piston during the run, and r = ratio of expansion,

$$p = \frac{V\,P}{\frac{U}{r} + V}$$

And the mean pressure on the piston, which may be taken as the measure of relative efficiency, will be

$$p_m = \frac{Hyp\,.\,log.\,r + 1}{r} \times \frac{V\,P}{\frac{U}{r} + V}$$

The curves here plotted show the values of p_m for various points of cut-off, in the case of the torpedoes now being built for the Ordnance Bureau, where $V = 7.5$ cubic feet and $P = 90$ atmospheres.



The upper curve is for a value of $U = 22.5$ cubic feet, and the lower for $U = 45$ cubic feet, corresponding to runs of about 1,200 and 2,400 feet, respectively. The economical point of cut-off, therefore, varies with the distance run, the maximum values of p_m being 35 per cent. and 25 per cent., respectively, for the two runs. That adopted in practice is .3 of the stroke.

INVESTIGATION OF THE LOSSES OF PRESSURE OF COMPRESSED AIR AND OF STEAM IN PIPES.*

BY CH. LEDOUX,

ENGINEER IN CHIEF OF MINES,
PROFESSOR AT L'ECOLE SUPERIEURE DES MINES.

I. COMPRESSED AIR.

IT is generally accepted that the loss of pressure in a straight horizontal pipe is proportional to the density of the gas, to the length of the pipe, to the square of the velocity, and inversely to the diameter.

This is expressed by the equation

$$z = K\delta\frac{L u^2}{D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

in which K is a constant, L and D the length and diameter of the pipe in meters, δ the weight of 1 cubic meter of the gas in kilogrammes, u its velocity in meters per second.

While working with air at low velocities, and at a pressure differing little from atmospheric pressure, Navier found for the value of the co-efficient K, 0.00110,

and Daubisson, 0.00114.

In a work published in 1880, in the *Revue Universelle des Mines*, second series, Vol. VII., Mr. Stockalper thought, by analogy with the equations for the flow of water in pipes, he could give for air the value

$$K = 0.001014 + \frac{0.00002588}{D}.$$

The experiments which he made at Saint Gothard upon two pipes, one 20 centimeters in diameter and 4,600 meters long, the other 15 centimeters in diameter and 522 meters long, do not appear to have confirmed these theoretical views; for the pressures observed

* Extract from the *Annales des Mines*, Nov., 1892. Translated from the French by S. D. Graydon.

at the end of the pipes were noticeably different from those which are derived from equation (1) when K is given the value indicated above.

The experiments at Anzin, of which I will give an account further on, appear to indicate that the co-efficient K is independent of the diameter, and the equations based upon the hypothesis that the value of this co-efficient is constant, give results which agree in a remarkable manner with the observations of Mr. Stockalper.

More recently Professor Riedler has made a great number of experiments in Paris upon the network of pipes of the Popp compressed air system. He has accepted the constancy of the co-efficient of loss of pressure, and assigns to it a value of 0.000533, say about one-half the figure of Navier.

The Popp pipes have, however, along their lines, a great many elbows and contractions due to valves, reservoirs and branches, adding their effect to that of friction. Above all, there are leaks whose importance is unknown, but is certainly very considerable, and whose influence upon the loss of pressure must not be ignored.

The figure given by Mr. Riedler cannot, therefore, inspire confidence, or, at least, raises doubts.

In view of these contradictory results I have had a number of tests made at Anzin, for the purpose of verifying the correctness of equation (1), and of ascertaining the value of the co-efficient K, both for compressed air and for steam, under the conditions of modern practice in mines.

Taking the equation

$$z = K\delta \frac{u^2 L}{D}$$

calling p_0, Q_0, T_0 the pressure in atmospheres, the volume in cubic meters, and the temperature absolute of the air, at the entrance to the pipe; p, Q, T the same elements at a point located at a distance x from the entrance; we have

$$\delta = 1.293 p \frac{273}{T} = \frac{353 p}{T}$$

the air being considered dry.

In reality, compressed air is nearly always moist; but the consequent difference in density is very slight, and may be neglected in the calculations which follow.

Also $$u = \frac{4\,Q}{\pi\,D^2}$$

$$Q = Q_0 \frac{p_0\,T}{p\,T_0}$$

from which

$$u = \frac{4\,Q_0\,p_0\,T}{\pi\,D^2\,p\,T_0}$$

For an increase of length dx of the pipe, the loss of pressure expressed in kilogrammes per square meter is equal to 10,334 dp, and we have $10334\,dp = -\frac{16.353\,K}{\pi^2} \cdot \frac{Q_0^2\,p_0^2\,T}{D^5\,p\,T_0^2}\,dx$

whence $$p\,dp = -\frac{0.0556\,K\,Q_0^2\,p_0^2\,T}{D^5\,T_0^2}\,dx$$

If we integrate between p_0 and p, and between zero and L, and if we assume that T is constant we get

$$p^2 = p_0^2 \left(1 - \frac{0.1112\,K\,Q_0^2\,T\,L}{D^5\,T^2}\right) \ldots\ldots\ldots\ldots\ldots (2)$$

It is easily demonstrated that this equation does not change if p and p_0 are expressed in kilogrammes absolute per square centimeter.

To prove this equation was the purpose of the tests at Anzin.

They were carried out by Mr. Barry, with an accuracy, skill and perseverance, to which I am glad to bear testimony.

These experiments were, in fact, much more difficult to carry to a successful conclusion than would, at first sight, be believed. They required great patience, gropings in the dark, and repeated trials, in order to insure the elimination, as far as possible, of the numerous causes of error which tend to falsify observations, and in order to obtain reliable results.

DESCRIPTION OF THE EXPERIMENTS.

At the outside of the Lambrecht moat three horizontal pipes were laid, nearly straight, of wrought iron, new, and having respectively an inside diameter of

0.100 meters and length of 294.20 meters.
0.074 " " " " 296.70 "
0.047 " " " " 295.20 "

They were connected with the receivers of a compressor by a pipe having several elbows and contractions.

At the two extremities of the straight part of the pipe serving for the experiments, was a close-ended branch pipe 0.07 m. in diameter and 0.05 m. long, carrying: 1, a hub to receive a Bourdon gauge 0.35 m. in diameter, graduated to $\frac{1}{50}$ of a kilogramme per square centimeter; 2, a small copper tube extending into the interior of the pipe, and into which a mercury thermometer was inserted.

The free end of the pipe was closed by a stop valve.

To the compressed air receivers was attached a manometer with free mercury column, but with reading scale reduced. The manometer served in the first place to measure the pressures in the tests of the delivery of the compressor, and then to standardize the Bourdon gauges. It was thus found out that the latter did not give readings identical with those of the mercury gauge.

The experimenters then prepared for each series of tests a table of corrections for the readings of the Bourdon gauges.

The compressor supplying the air was of the Sommelier type.

In a preliminary set of tests its delivery had been determined for various speeds. It was demonstrated that, despite the precaution taken to avoid the effect of clearance, a uniform delivery could not be accomplished. The following are the results obtained:

Rev per Min. of Compressor.	First Set of Experiments. Delivery.	Second Set of Experiments. Delivery.	Third Set of Experiments. Delivery.	Average.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
10	88	93.17	89	90.6
15	89	92.40	.....	90.7
20	89	92.83	91.16	90.9
25	88	90.85	.....	89.2
30	86.5	88.45	.....	87.5

These are the figures for average delivery which have been used in the calculations.

The course followed in each set of experiments was as follows:

The reservoirs were filled with compressed air, and the connection with the experimental pipe was opened. Three observers

stationed themselves—one in the engine-room, the second at the entrance to the experimental pipe, and the third at its end.

The stop valve was gradually opened, to hold the compressor to as uniform a speed as possible up to that which is reached in a regular refrigerating system, this condition being maintained during a fixed time (three to six minutes).

At both extremities of the pipe, the observers made three groups of two simultaneous readings while the one in the compressor room noted: 1. The pressure and the temperature of the room, which would not vary during the progress of an experiment; 2. The number of revolutions of the compressor; 3. The time elapsed. Frequently the three readings gave identically similar results.

Whenever there was a difference, the average of the pressures noted was taken. Moreover, knowing the volume of the reservoir, we could increase or decrease the volume of air supplied by the compressor and calculate from the number of revolutions and the delivery the quantity of air in excess remaining in the reservoir or supplied by it.

In each experiment it was made certain that the cylinders of the compressor were full of water.

Taking up again the equation

$$p^2 = p_0^2 - \frac{0.1112\, K\, Q_0^2\, p_0^2\, T\, L}{D^5\, T_0^2}$$

we derive from it

$$K = \frac{(p_0^2 - p^2)\, D^5}{0.1112\, L\, T \left(\frac{Q_0\, p_0}{T_0}\right)^2} \quad \ldots\ldots\ldots\ldots \quad \ldots.(3)$$

or

$$\frac{P_0\, Q_0}{T_0} = \mu\, \frac{n\, v\, p'}{60\, T'}$$

calling μ the delivery of the compressor, n the number of revolutions per minute, v the volume swept through by the piston per revolution, p' and T' the barometric pressure and the absolute temperature of the compressor room. In case $v = 0.7636$ cubic meters we have all the necessary data for the determination of K.

The following table gives the results of 34 experiments made on February 28 and 29, 1892:

Date and Number of Experiments.		Total Revolutions of Compressor.	Duration of Experiment.	Compressor Room. Barometric Pressure. Kilogrammes.	Compressor Room. Temperature. Deg. Cent.	Initial Station. p_0 Kilogr.	Initial Station. T_0 Deg. Cent.	Final Station. p Kilogr.	Final Station. T Deg.	Pressure (relative) in Reservoir. At Beginning of Experiment.	Pressure (relative) in Reservoir. At End of Experiment.	Volume of Reservoir. Cubic Meters.	$p_0 - p$.	Velocity Average. Meters.	K.	Average Values of K.	Remarks.
							First Series. $D = 0.10$ m. $L = 294.2$ m.										
			M. S.							Kilogr.	Kilogr.						
Feb. 28.	1	134 (about 30 per min)	4 28	1,024	291	5,650	278	5,552	274	Constant.		38.2607	0.098	7,490	0.00088		Probably an error. Was not used in determining K.
"	2	102	3 18	.....	.....	4,787	279	4,703	.....	.....	.....	.....	0.084	9,125	0.00060	.....	
"	3	128 "	4 16	.....	293	3,914	281	3,800	.....	.....	.....	.....	0.114	17,825	0.00072		
"	4	183 "	5 58	.....	294	2,449	282	2,176	.....	.....	.....	.....	0.273	18,673	0.00097		
"	5	124 "	4 3	.....	.....	1,747	.....	1,378	.....	.....	.....	.....	0.369	27,675	0.00090		
"	6	142 (25) "	5 36	.....	.....	1,727	.....	1,456	279	.....	.....	.....	0.271	23,053	0.00094	0.00087	Average of 9 experiments.
"	7	124 "	4 58	.....	294.5	2,777	.....	2,666	.....	1.900	1.974	.....	0.111	12,741	0.00073		
"	8	130 (20) "	6 8	.....	.....	2,844	.....	2,748	.....	Constant.		.....	0.096	11,116	0.00081		
"	9	104 "	5 4	.....	.....	1,747	.....	1,569	279.5	.....	.....	.....	0.178	18,215	0.00094		
"	10	85 "	5 45	.....	295	1,477	.....	1,370	.....	.....	.....	.....	0.107	15,166	0.00095		Probably an error. Not used in determining K.
"	11	54 (10) "	5 5	.....	294	1,402	.....	1,370	280.5	.....	.....	.....	0.032	11,403	0.00053	.....	
							Second Series. $D = 0.047$ m. $L = 295.20$ m.										
Feb. 28.	13	22 (about 10 per min)	2	1,024	294	2,968	279.5	2,252	279.5	1.967	2.000	38.2607	0.716	26,298	0.00057	.....	Probably an error. Not used in determining K
"	14	59 "	5 52	.....	294 5	3,917	279	3,214	280.5	2.864	2.957	.....	0 703	17,353	0.00092		
"	15	32 "	3 6	.....	295	4,787	.....	4,159	280	Constant.		.....	0.628	15,364	0 00082		
"	16	37 "	3 41	.....	.....	5,761	.....	5,303	279.5	.....	.....	.....	0.458	12,039	0.00083		
Feb. 29.	2	72 (15) "	4 51	1,023	294	5,581	278	4,043	273.5	.....	.....	.....	1 538	20,558	0.00107		
"	3	86 "	5 30	.....	293	4,859	280	2,213	274	3.917	3.843	.....	2.646	35,068	0.00110		
"	4	65 "	4 10	.....	292.5	5,957	.....	4,505	275.5	Constant.		.....	1.452	19,994	0.00097	0.00092	Average of 12 experiments.
"	5	89 "	5 56	.....	291	3,942	.....	1,273	274.5	.....	.....	.....	2.649	51,240	0.00095		
"	6	100 (20) "	5 2	.....	293	5,781	281	3,211	277.5	.....	.....	.....	2 570	31,850	0.00090		
"	7	100 "	5	.....	291.5	5,502	282	1,987	279.5	4.506	4.445	.....	3.515	47,282	0 00094		
"	8	83 "	4 9	.....	292	5,170	283	1,236	282	4.233	4.171	.....	3 934	70,056	0.00088		
"	9	105 (25) "	4 14	.....	291.5	5,812	284	1,190	284	Constant.		.....	4.622	83,256	0.00082		
"	10	63 (10) "	6 19	.....	292	2,480	281	1,326	.....	1.378	1.535	.....	1.154	33,876	0 00089		
							Third Series. $D = 0.71$ m. $L = 296.7$ m.										
Feb. 29.	11	159 (about 30 per min)	5 15	1,023	290	5,705	284	5,073	279	Constant.		38.2607	0.632	15,906	0.00094		
"	12	127 "	4 14	.....	289.5	4,923	285	4,190	.....	4.053	4.000	.....	0.724	19,155	0.00089		
"	13	132 "	4 25	.....	.....	3,952	284	2,961	.....	3.137	3.060	.....	0.991	25,647	0.00092		
"	14	116 "	3 51	.....	289.5	3,105	285	1,688	278	Constant.		.....	1.507	38,396	0.00103	0.00094	Average of 9 experiments.
"	15	273 "	7 10	.....	.....	2,681	286	1,268	277	1.775	2.014	.....	1.413	45,485	0.00092		
"	16	168 (43) "	6 45	.....	.....	2,404	285	1,228	285	1.482	1.585	.....	1.176	43,526	0 00088		
"	17	97 "	3 54	.....	.....	3,289	.....	2,459	276.5	2.393	2.433	.....	0.830	24,961	0 00099		
"	18	80 "	3 15	.....	290	4,036	284	2,497	278.5	3.080	3.137	.....	1,539	22,158	0,00221	.....	Probably an error. Not used in determining K.
"	19	90 "	3 40	.....	.....	5,116	.....	2,705	276.5	Constant.							
"	20	129 "	5 10	.....	290.5	5,066	.....	5,479	276								

If we except experiments 2 and 11 of the first series, 13 of the second and 18 of the third, or four out of the thirty-four which differ too greatly from the others not to be tainted with errors of observation, the values found for K and calculated by equation (2) exhibit a remarkable agreement, and that, too, in spite of considerable fluctuations in speed, it varying from 7 to 83 meters per second.

With the 10-centimeter pipe, the average of nine experiments gives $K = 0.00087$ with a maximum deviation about this figure of 0.00015.

With the 0.047-meter pipe, the average of 12 tests out of 13 gave $K = 0.00092$ with a maximum deviation of 0.00015. Finally, with the 0.071-meter pipe, the average of 9 tests out of 10 gives $K = 0.00094$ with a maximum variation of 0.00017. The mean of these three values is 0.00091.

STOCKALPER'S EXPERIMENTS.

It is interesting to prove if this value of K agrees with those which can be deduced from the experiments at Saint Gothard.

The following table gives a *résumé* of the data from those tests and the value of K calculated from these data by equation (3). The paper of Mr. Stockalper does not state the temperature at the entrance and exit of the pipes, but only the average temperatures.

I have assumed in the computations that $T_0 = T =$ the average absolute temperature:

Number of Experiment.	Diameter of Pipe.	Length of Pipe.	Initial Volume Reduced to 0° and 760 m.m.	Initial Volume Reduced to the Initial Pressure and Average Temperature.	Initial Pressure p_0	Final Pressure p.	Loss of Pressure $p_0 - p$.	Average Temperature $T_0 = T$.	Average Velocity of the Air in the Pipe.	Values of K Calculated by Equation (3).	Remarks.
	Met.	Met.	Cu. M.	Cu. M.	Atm.	Atm.	Atm.	Deg.	Met.		
1	.20	4,600	0.936	0.178	5.66	5.24	0.42	294	5.89	0.00083	
2	.15	522	0.936	0.195	5.24	5 00	0.24	299.5	11.29	0.00091	
3	.20	4,600	0.623	0.154	4.35	4.13	0.22	294	4.97	0.00063	(1)
4	.15	522	0.623	0 165	4.13	4.06	0.07	299.5	9.37	0.00040	(1)
5	.20	4,600	0.520	0.146	3.84	3.65	0.19	294	4.74	0.00090	
6	.15	522	0.520	0.156	3.65	3.545	0.105	299.5	8.92	0.00083	

(1) Probably errors of observation.

The values of K, which result from tests Nos. 1, 2, 5 and 6, agree in a remarkable manner with each other, and with those which the experiments at Anzin developed.

In fact they give

For D — 0.20 m., K — 0.00083 and 0.00090, or an average of 0.000865.
For D — 0.15 m., K — 0.00091 and 0.00083, or an average of 0.000870.

This is a general average of 0.00087.

The Anzin tests give 0.00091.

When the difficulties and the numerous sources of error in these tests are considered, it must be admitted that the agreement is as satisfactory as possible, especially when it is noted that the pipe upon which Mr. Stockalper experimented, being at least 5122. meters long, had in all probability leaks whose effect should be to diminish the loss of pressure.

In reference to the tests Nos. 4 and 5, whose results vary noticeably from the others, Mr. Stockalper admits that they are due to errors in observation.

I therefore believe that we can accept with confidence the figure 0.00091 obtained by the Anzin experiments.

CONCLUSION.

The conclusions arrived at from the preceding discussion are as follows—viz.:

1. The law expressed by the equation

$$z = K \delta \frac{L u^2}{D}$$

may be regarded as exact, at least within the limits of the velocities in the above experiments.

2. The co-efficient K is constant, and equal to 0.00091 in a straight horizontal pipe.

3. The equation which gives the pressure p at the end of a straight horizontal pipe, into which enters a volume Q_0 at the pressure p_0 and the temperature T_0 is

$$p^2 = p_0^2 \left(1 - 0.0001012 \frac{Q_0^2 \, T \, L}{T_0^2 \, D^5} \right) \quad \ldots\ldots\ldots (4)$$

4. If the pressure, the initial volume, the loss of pressure, and the length of the pipe are given, the corresponding diameter can be found by the equation

$$D = \sqrt[5]{\frac{0.0001012\ Q_0^2\ T\ L}{T_0^2\left(1-\frac{p^2}{p_0^2}\right)}}$$

or,
$$D = 0.1589\sqrt[5]{\frac{Q_0^2\ T\ L}{T_0^2\left(1-\frac{p^2}{p_0^2}\right)}} \quad \ldots\ldots\ldots\ldots (5)$$

In order to facilitate the solution of equations (4) and (5), I have constructed Charts I. and II., which enable the rapid finding of any one of the elements D, p_0, Q_0, p, L, with a degree of approximation quite sufficient in practice, when the others are known.

Taking a common case, $T_0 = 288$ and T (the average temperature of the interior of the pipe) $= 293$, if Q_0 be expressed in cubic meters per minute, and D in centimeters, equation (5) becomes, by placing $D' = 100\ D$ and $Q'_0 = 60\ Q_0$.

$$D' = 0.9987\sqrt[2]{\frac{Q'^2_0\ T\ L}{1-\frac{p^2}{p_0^2}}} \quad \ldots\ldots\ldots\ldots (5\tfrac{1}{2})$$

Letting
$$\frac{L}{1-\frac{p^2}{p_0^2}} = C,$$

and substituting logarithms,

$$\log.\ D' = \log.\ 0.9987 + \tfrac{2}{5}\log.\ Q_0' \times \tfrac{1}{5}\log.\ C.$$

Making $\log.\ D' = Y$, and $\frac{2}{5}\log.\ Q_0' = X$, it appears that for each value of C the curve represented by the equation

$$Y = \log.\ 0.9987 + \tfrac{1}{5}\log.\ C + X$$

will be a straight line inclined at 45 degrees.

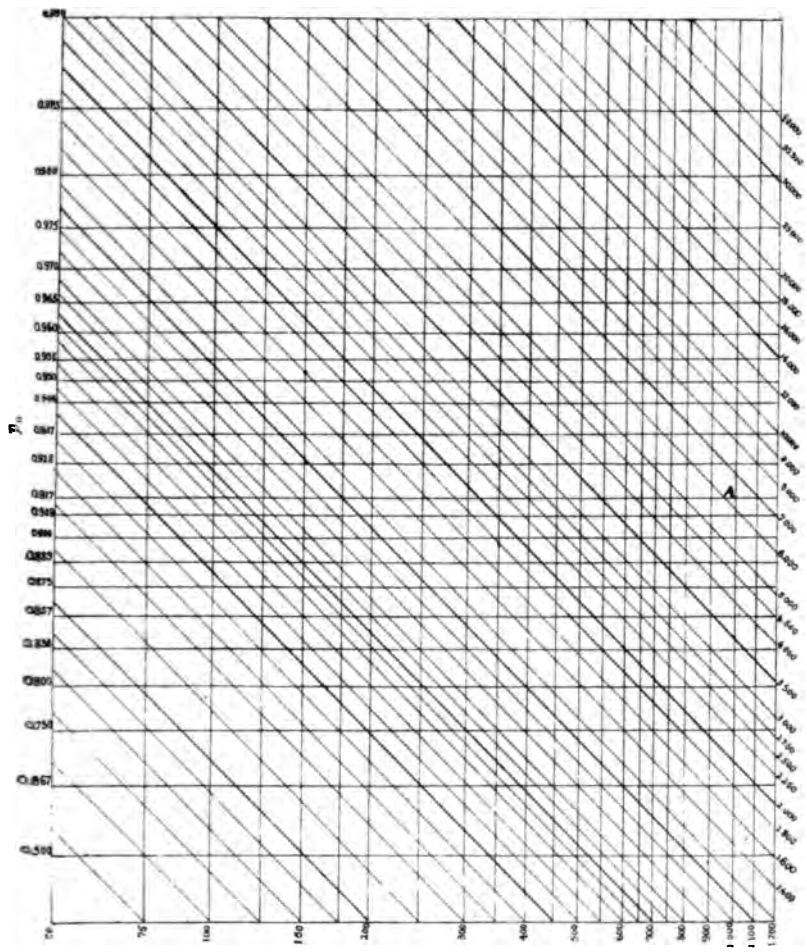
These lines are traced upon Chart II. for a certain number of values of C.

In order to calculate C, a function of L and of $\frac{p}{p_0}$, Chart I. should be used.

We have, $\log.\ C = \log.\ L - \log.\left(1-\frac{p^2}{p_0^2}\right)$

CHART I.

Showing values of the function $C = \dfrac{L}{1 - \left(\dfrac{p}{p_0}\right)^2}$ for compressed air.



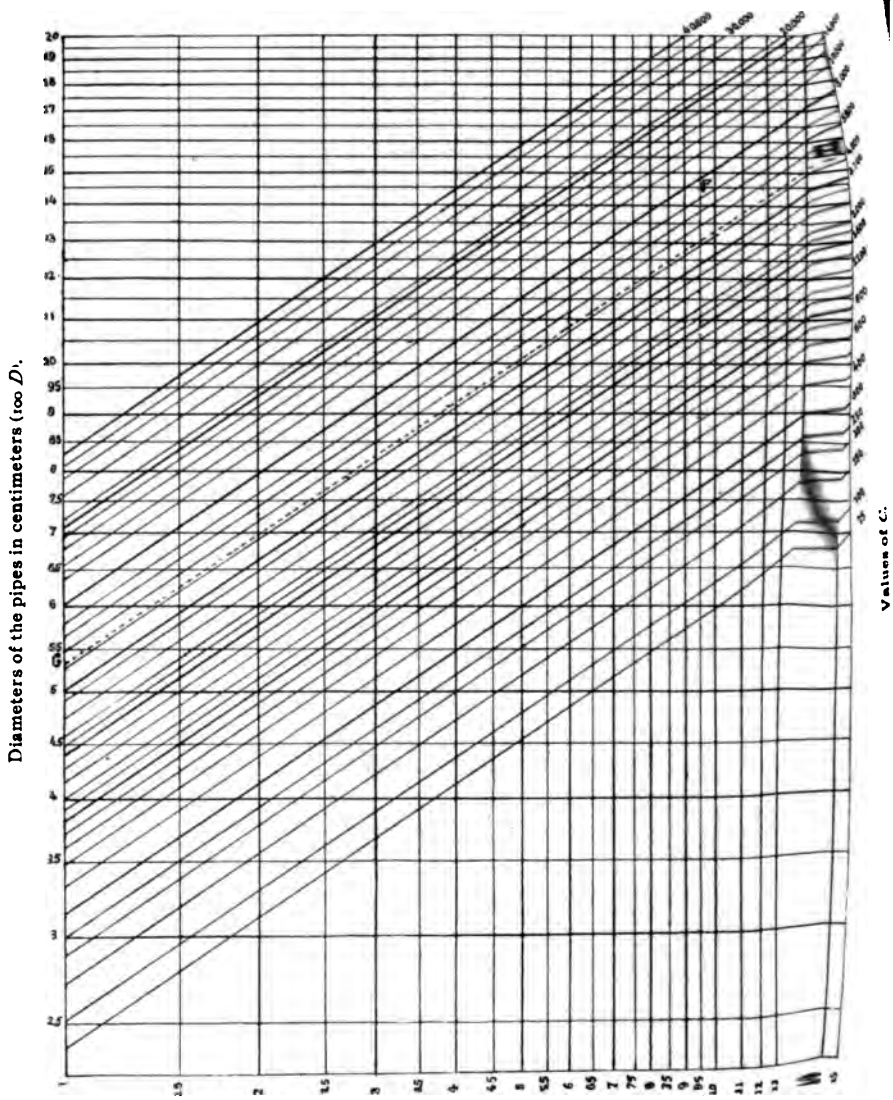
Lengths L, of pipes in meters, and values of C.

CHART II.

Volumes of compressed air delivered by pipes of different diameters for given values of C.

NOTE.—The dotted line $G\,H$ shows the diameter of a vertical descending pipe in which the loss of pressure is zero.

Values of C.



Making $\log. L = X$, and $\log. \left(1 - \frac{p^2}{p_0^2}\right) = Y$,

we get $$Y = X - \log. C,$$

that is to say, that this equation represents a series of straight lines whose position depends upon the value of log. C.

The application of these charts is quite easy. Suppose it is sought to ascertain the proper diameter for a pipe 1,000 meters long, having to deliver from the entrance 10 cubic meters of air compressed to C atmospheres, with a loss of one-half atmosphere at the end.

$$p = 5.5.\ p_0 = 6.\ \frac{p}{p_0} = 0.917.$$

Chart I. shows that the point of intersection of the ordinate passing the abscissa 1000 with the abscissa corresponding to 0.917 is found at a point A between the oblique lines marked 6000 and 7000 at a distance above the former about equal to one-third of the distance between them. We have, therefore, $C = 6333$.

Referring to Chart II. and taking the line marked 6400, which differs but little from the above figures, we see that this line cuts the ordinate 10 at the point F, which is a little below the horizontal line corresponding to the diameter 14.5.

If we make the computation directly by equation (5½), we find $D = 14.41$. The approximation is very satisfactory.

THE CASE OF AN INCLINED PIPE.

The calculations which precede assume that the pipe is horizontal. If there is a difference of level between the entrance and the exit, there is an increase or decrease of pressure on account of the effect of gravity according as the pipe inclines upward or downward.

Call the angle made by the straight pipe with the horizon α.

The increment of the pressure due to gravity (a positive or negative increment according as α is itself positive or negative) is for an increase of length $d\,L$, equal to the weight of the element whose height is $d\,L \sin. \alpha$.

We have, therefore, $10334\ d\,p = \delta\ d\,L \sin. \alpha$, δ being the density of the air at the point under consideration.

And, as $\delta = \frac{353\,p}{T}$, the differential equation becomes, after

all reductions,

$$dp = \frac{0.0341\, p \sin.\ \alpha}{T}\, dL.$$

If the air be not in motion the pressure at the end of the pipe will be given, after integrating between p_0 and p and between zero and L by the equation

$$\text{log. nep.}\ \frac{p}{p_0} = \frac{0.0341\, L \sin.\ \alpha}{T}, \text{ or } p = p_0\, e^{\frac{0.0341\, L \sin.\ \alpha}{T}} \quad \ldots (6)$$

α being taken positive if the pipe inclines downward, negative if upward.

If the air travels along the pipe, the differential equation becomes, after adding the loss of pressure due to friction:

$$dp = \frac{0.0341\, p \sin.\ \alpha}{T}\, dL - \frac{0.0000506\, Q_0^2\, p_0^2\, T}{D^5\, p\, T_0^2}\, dL,$$

$$\text{whence } dL = \frac{p\, dp}{\frac{0.0341 \sin.\ \alpha}{T}\, p^2 - \frac{0.0000506\, Q_0^2\, p_0^2\, T}{D^5\, T_0^2}}.$$

Integrating between zero and L and between p_0 and p, we find:

$$\frac{0.0682 \sin.\ \alpha\, L}{T} = \text{log. nep.} \frac{p^2 - \frac{0.001484\, Q_0^2\, p_0^2\, T^2}{\sin.\ \alpha\, D^5\, T_0^2}}{p_0^2 - \frac{0.001484\, Q_0^2\, p_0^2\, T^2}{\sin.\ \alpha\, D^5\, T_0^2}} \quad \ldots . (7)$$

from which

$$p^2 = \frac{0.001484\, Q_0^2\, p_0^2\, T^2}{\sin.\ \alpha\, D^5\, T_0^2} \left[1 + \left(\frac{\sin.\ \alpha\, D^5\, T_0^2}{0.001484\, Q_0^2\, T^2} - 1 \right) e^{\frac{0.0682 \sin.\ \alpha\, L}{T}} \right] \ldots . (7_2)$$

Upon developing the term $e^{\frac{0.0682 \sin.\ \alpha\, L}{T}}$ into a series and making sin. $\alpha = 0$, we return to equation (4), which was established for the case of a horizontal pipe.

An examination of equation (7) leads to an interesting conclusion.

If we make

$$\sin.\ \alpha\, D^5\, T_0^2 = 0.001484\, Q_0^2\, T^2$$

whence

$$D = 0.2718 \sqrt[5]{\frac{Q_0^2\, T^2}{\sin.\ \alpha\ T_0^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

we see that $p = p_0$, that is to say, that the increase of pressure due to gravity offsets the loss of pressure due to friction, when D satisfies equation (8), whatever may be the value nevertheless, of the initial pressure and the length of the pipe.

In a vertical pipe there will, therefore, be no loss of pressure when the diameter fulfills the condition

$$D = 0.2718 \sqrt[5]{\frac{Q_0^2\, T^2}{T_0^2}}$$

In the case of an air shaft we may assume, without sensible error that $T = T_0$. Then the equation (8) becomes

$$D = 0.2718 \sqrt[5]{Q_0^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8_2)$$

This value of D has been adopted in practice for pipes set in air shafts.

If it is desired to express D in centimeters and Q_0 in cubic meters per minute, we place $100\ D' = D$, and $60\ Q_0 = Q_0'$. the preceding equation then becomes:

$$D' = 5284. \sqrt[5]{Q_0'^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8_3)$$

The dotted line $G\,H$ on Chart II. gives the values of D' deduced from equation (8_3) for values of Q_0 between 16.7 liters and 250 liters per second, or 1 to 15 cubic meters per minute.

The following table gives them for the more common deliveries of 1, 2, 3, 4 and 5 cubic meters per minute.

Delivery.		Diameter of Pipe in Centimeters.
In Liters per Second.	In Cu. M. per Min.	
16.7	1	5.28
33.3	2	6.97
50.	3	8.20
66 7	4	9 20
83.3	5	10.06

Note. If D fulfills the condition (8_3) there will be no loss of pressure, that is to say the *absolute* pressure of the compressed air will be the same at the bottom of the shaft as at the mouth. But

the *effective* pressure will not be the same, since the outside air will be below at a pressure greater than at the mouth by a quantity which cannot be ignored. The atmospheric pressure above being 1, the pressure below will be $e^{\frac{0.0341\ L}{T}}$.

In order that the effective pressure shall remain constant, it is necessary to have such a diameter D, that the pressure p on the inside of the pipe at the bottom shall be equal to $p_0 + e^{\frac{0.0341\ L}{T}}$. Substituting this quantity for p in equation (7), we have the required value for D.

Consider for example a shaft 500 meters deep, in which the average temperature is 15°.

The pressure at the bottom expressed in atmospheres, will be

$$e^{\frac{0.0341 \times 500}{288}} \text{ or } 1.061 \text{ atmospheres,}$$

or expressed in kilogrammes per square meter $10334 \times 1.061 = 10965$ kilogrammes, an increase of pressure of 631 kilogrammes.

If the initial pressure is 6 atmospheres, the values of D' for which the *effective* pressure will be the same at top and bottom will be the following :

For Q_0 —	16.7 liters,	33.3 l.	50 l.	66.7 l.	83.3 l.
" D' —	5.5 c. m.	7.2 c. m.	8.5 c. m.	9.5 c. m.	10.4 c. m.

that is from 2 to 4 millimeters more than by the preceding table.

Leakages. We have hitherto assumed the pipe to be tight.

If it has leaks, their effect will necessarily be to diminish the loss of pressure, since the volume of gas which passes any point is less by the volume which has escaped during its previous travel.

In this case the loss of pressure can be computed in the following way.

Let β be the loss in weight of gas per second, and per meter of length of pipe.

In fact, β varies with p; but in order not to complicate the calculations excessively we may consider it constant.

Calling m_0 the initial weight of air entering the pipe, m the weight at a point situated at a distance x from the entrance, we have

$$m = m_0 - \beta x.$$

If Q_0 and Q be the volumes, p_0 and p the pressures, T_0 and T the absolute temperatures at the same points we have

$$Q_0 = \frac{10334}{1.293 \times 273} \frac{m_0 T_0}{p_0} = 29.272 \frac{m_0 T_0}{p_0}$$

and $$Q = 29.272 \frac{m T}{p} = \frac{29.272 (m_0 - \beta x) T}{p}$$

The density $\delta = \frac{353 p}{T}$, and the velocity of the fluid at the point under consideration is

$$u = \frac{4 \times 29.272 (m_0 - \beta x) T}{\pi D^2 p}.$$

The differential equation for the loss of pressure is

$$10334\, dp = -\frac{K \delta u^2 dx}{D} = -\frac{16 K}{\pi^2 D^5} \times \frac{353 \times \overline{29.272^2} (m_0 - \beta x)^2 T dx}{p}$$

whence $$p\, dp = -\frac{47.471 K T}{D^5} (m_0 - \beta x)^2 dx$$

or finally $$p_0^2 - p^2 = \frac{94.942 K T}{D^5} \left(m_0^2 - \beta m_0 L + \frac{\beta^2 L^2}{3} \right) L$$

Making $\beta = 0$, $$m_0 = \frac{Q_0 p_0}{29.272 T_0}$$

brings us back to equation (2).

Taking $K = 0.00091$ we derive finally

$$p_0^2 - p^2 = \frac{0.0864 T}{D^5} \left(m_0^2 - \beta m_0 L + \frac{\beta^2 L^2}{3} \right) L \ldots\ldots (9)$$

The quantity β can be determined of course only by experiment, and this determination presents no difficulty in a given pipe or system of pipes.

It is indeed sufficient to fill the pipe with compressed air after closing all openings, and note in what time the pressure falls 1 atmosphere, for example. Knowing the volume of the pipe, the loss of weight which is caused per second or per meter of length by leaks can be deduced.

Loss of Energy. Compressed air is always employed as a motive force. It is therefore necessary to consider the loss of energy, consequent upon the loss of pressure due to friction.

In practice this loss of energy manifests itself by a falling off in the available work at the end of the pipe, and the latter depends upon the kind of motor.

If the motor is for full pressure such as drills and many of the small motors operating elevators or ventilators, the available work indicated at the exit of a horizontal pipe, is $10334\ (p - 1)\ Q$.

At the entrance to the pipe the available work was $10334\ (p_0 - 1) Q_0$; the relative loss of work due to friction is

$$\frac{p_0\ Q_0 - p\ Q + Q - Q_0}{(p_0 - 1)\ Q_0}.$$

Usually T varies little from T_0, consequently $p_0\ Q_0$ differs little from $p\ Q$. If we make $p_0\ Q_0 = p\ Q$ the preceding expression becomes $\frac{Q - Q_0}{(p_0 - 1)\ Q_0}$, and as $\frac{Q}{Q_0} = \frac{p_0}{p}$ we finally obtain for the proportional loss of work $\frac{p_0 - p}{p\ (p_0 - 1)}$. This is proportional to the loss of pressure, and for the same loss of pressure it decreases according as p_0 increases.

Supposing now that the motor is an expansion engine and that the final volume is equal to n times the volume of compressed air admitted, that is to say that the number of expansions is n.

We know that if there is no reheating of the air in the interior of the cylinder, that is, if the expansion takes place without addition or subtraction of heat, the pressure and volume are connected by the relation $p\ Q^{1.41} = \text{const.}$

The available work of a volume Q of compressed air at the pressure p, expanding to n times its volume is:

$$W = \frac{10334\ p\ Q}{0.41}\left[1.41 - \left(\frac{1}{n}\right)^{0.41}\right] - 10334\ n\ Q$$

or $$W = p\ Q\ 35539 - 25205\left(\frac{1}{n}\right)^{0.41}\Big] - 10334\ n\ Q.$$

The proportional loss of work will be

$$\frac{(p_0\ Q_0 - p\ Q)\left[35539 - 25205\left(\frac{1}{n}\right)^{0.41}\right] + 10334\ n\ (Q - Q_0)}{p_0\ Q_0\left[35539 - 25205\left(\frac{1}{n}\right)^{0.41}\right] - 10334\ n\ Q_0}.$$

If T equals T_0, $p_0\ Q_0 = p\ Q$, and the proportional loss becomes

$$\frac{n\,(Q - Q_0)}{p_0\ Q_0\left[3{\cdot}439 - 2{\cdot}439\left(\frac{1}{n}\right)^{0{\cdot}41}\right] - n\ Q_0}$$

or

$$\frac{n\,(p_0 - p}{p_0\ p\left(3{\cdot}429 - 2{\cdot}439\,\frac{1}{n^{0{\cdot}41}}\right) - n\,p.}$$

It is again proportional to the loss of pressure, and decreases as the initial pressure increases.

Finally, supposing the motor to be such, that the pressure at the end of the expansion shall be equal to the atmospheric pressure. The degree of expansion $n = p^{\frac{1}{1{\cdot}41}} = p^{0{\cdot}709}$ and the available work is

$$W = Q\,(35539\,p - 14871\,p^{0{\cdot}709}).$$

The proportional loss, assuming $p_0\ Q_0 = p\ Q$ is

$$\frac{W'_0 - W}{W_0} = \frac{p_0{}^{0{\cdot}291} - p^{0{\cdot}291}}{(2{\cdot}39 - p_0{}^{0{\cdot}291})\,p_0{}^{0{\cdot}291}\,p^{0{\cdot}291}}$$

In practice the greatest expansion of compressed air is realized only by reheating it either previously, before admission, or by injecting water during expansion.

The investigation of the loss of work in these various cases involves considerations which would not be appropriate in this memoir.

(TO BE CONTINUED.)

RADIATION AND ABSORPTION OF HEAT BY LEAVES.

BY ALFRED GOLDSBOROUGH MAYER, M. E., '89.

RESULTS OF THE EXPERIMENTS.*

IN conducting the experiments upon radiation it was deemed wise to select leaves of widely different genera of plants; accordingly, the leaves of a few forest trees, bushes, weeds living in both sunny and shady places, aquatic plants, cultivated plants, and grasses were chosen. The results of a series of experiments upon the following leaves demonstrated that the co-efficient of radiation of dark heat from both their upper and lower surfaces was *exactly* the same as that of lampblack.

The leaves tested were elm, oak, maple, horse chestnut, basswood (*Tilia Americana*), silver poplar, beech, lilac, mullein (*Verbascum thapsus*), plantain (*P. major*), lilly pads (*Nuphar advena*), cultivated grape, blackberry and clover. A single interesting exception, however, was discovered. The upper surface of burdock leaves (*Arctium lappa*) radiates exactly as do all other leaves, but the *under* surface radiates only 81 per cent. of this amount.

These leaves are very broad and thick, and as they lie for the most part spread out horizontally very near the ground, the under surface is largely shaded from the sun's rays, and therefore receives but little direct heat. Moreover, it is probable that being so near to the ground less dew would form upon the under surface than upon the upper. Both of these causes would combine, as we shall see later, to make it very advantageous to such leaves to possess a poorly radiating lower suface.

Of course, as leaves radiate exactly as lampbacked surfaces, they also possess correspondingly good absorbing surfaces. Numerous experiments were made by the method already described to ascertain the effect of dew upon the radiation of leaves. If we call the radiation from a dry leaf 100, that from a leaf covered by a thin film of dew is about 78, and if the dew stand out in beads over the surface, the radiation is reduced to 66.

* Extract from a paper on the above subject in *The American Journal of Science*, Vol. XLV., April, 1893.

A polished tin surface, which only radiated 14 per cent. as much heat as a lampblacked surface, radiated 96.8 per cent. of the lampblacked one when both were covered with beads of dew. The co-efficient of radiation of the lampblacked surface was lowered, and that of the polished one raised, until the radiation was nearly the same from both. So potent is a film of dew in altering the nature of a radiating surface.

Upon the importance of this remarkable fact we need hardly dwell. The surface of leaves being one of the best known radiators of heat, is therefore an equally good absorber of that heat. If then we imagine a forest in the tropics where the days and nights are of almost equal length the whole year round, very much of that heat which had been absorbed by the leaves during the day, would be lost by their great radiation during the night, were it not for the fact that the blanket of dew which covers them cuts down this radiation to two-thirds of its former value.

In the experiments upon the absorption of heat by the leaves, considerable individual difference was found in different specimens of the same species of leaf. In stating the results therefore I shall give the range of variation, where necessary. The following table gives the percentages of heat absorbed and transmitted by single leaves of the species named:

Name of Leaf.	Transmits.	Absorbs.
Ash	19.7 per cent.	80.3 per cent.
Elm	18–23	77–82
Maple	16–20	80–84
Wild Cherry	15–18	82–85
Horse Chestnut	19	81
Lilac	14–18	82–86
Mullein (*V. thapsus*)	17	83
Burdock (*A. lappa*)	14	86
Chicory (*Chicorium intybus*)	17	83
Rose leaves	28–31	69–72
Petals of red rose (cultivated)	33	67
" " white rose	27	73
" " yellow rose	24	76
" " Oenothera speciosa	28	73
" " Tradescantia Virginica	31	69

The above table would seem to indicate that if dark heat be allowed to pass through a leaf, rather more than 80 per cent. is absorbed by the leaf and somewhat less than 20 per cent. transmitted.

The heat passes through exactly as readily when it enters by the lower surface as when it enters the upper.

The absorption of heat by leaves is highly selective. Thus a single elm leaf in the path of the dark radiant heat transmits 20 per cent. of the heat which entered it. If now the heat which has passed the first leaf be allowed to fall upon a second, it will be found that only 78 per cent. of it will be transmitted. A third leaf will transmit over 83 per cent. of the heat which passed through the second, and the effect of a fourth leaf is hardly noticeable. This may in some measure account for the somewhat remarkable fact that there is no very great difference between the absorbing abilities of such leaves as mullein and wild cherry, although the former are thick tough leaves and the latter very thin. By dissolving the chlorophyl out of leaves and again testing them, as has been explained under methods of experimenting, it was found that this substance absorbs but little of the dark heat. Thus, wild cherry leaves transmitted 9. per cent. and chicory (*C. intybus*) 4. per cent. more heat when their chlorophyl was abstracted by ether or alcohol. In thick tough leaves, such as lilac or elm, however, I was unable to detect its influence. It will be seen upon referring to the table that rather more heat seemed to be transmitted by the petals of flowers than by leaves. Natural selection has forced all leaves to the optimum as regards transmission and absorption of heat, and hence we find but little difference in the behavior of leaves of widely-different genera of plants in this respect. Their surfaces have become the best known absorbers of heat, and in order to counterbalance the consequent disadvantage of being the best of radiators, the dew, which collects upon them at night, cuts that radiation down.

MIDWINTER MEETING OF THE ALUMNI ASSOCIATION.

THE semi-annual meeting of the Alumni Association was held in the Hall of the Stevens School, on February 15. When the President, Mr. C. J. Field, called the meeting to order, there was present a larger attendance than usual on these occasions.

The minutes of the preceding meeting, as printed in the INDICATOR, were, upon motion of Mr. Raque, approved.

The President referred in favorable terms to the industry of the Executive Committee; and called for a report from Professor Riesenberger, one of the custodians of the Alumni Building Fund.

The latter presented a tabulated statement of subscriptions, classified as follows:

Class of 1875, has subscribed	$775, and $500 conditionally.
Class of 1876, " "	1,375.
Class of 1877, " "	550, and $100 conditionally.
Class of 1878, " "	400.
Class of 1879, " "	nothing.
Class of 1880, " "	325.
Class of 1881, " "	590, and $500 conditionally.
Class of 1882, " "	305.
Class of 1883, " "	560.
Class of 1884, " "	1,260.
Class of 1885, " "	1,170.
Class of 1886, " "	200.
Class of 1887, " "	550.
Class of 1888, " "	625.
Class of 1889, " "	525.
Class of 1890, " "	815.
Class of 1891, " "	700.
Class of 1892, " "	30.
Class of 1893, " "	530.
From outside subscribers and professors	4,065.

Subscribed unconditionally, $14,850; conditionally, $1,900.

This makes a grand total of $16,750. He also reported $6,428.72 of this amount collected, of which $5,300 was already bearing interest.

President Morton expressed his confidence that a judicious step had been taken, in beginning the collection of the fund, to which additions will be more readily attracted, and which will grow by its own earnings.

He stated that the action of the Trustees in reference to the fund would be conservative, and that no risk would be incurred in the erection of buildings except as funds are provided, even if the number of students yearly admitted shall have to be limited to the present capacity of the Institute.

The resources of the Institute will, however, enable moderate enlargements of the present buildings to be made sufficient to carry another year's larger class.

By that time the subscriptions to and collections for this fund may admit of proceeding with a portion of the plan; as, say, the erection of one wing of the desired building. In no event, however, would he consent to the diversion of any part of the fund from its original purpose—namely, the erection of a chemical and physical laboratory, to some relatively temporary improvement.

Professor Mayer called attention to the fact that his subscription had been made toward the erection of laboratories for chemistry and physics, whereas the title, Alumni Building Fund, is general and uncertain.

"If," said Professor Mayer, "a man subscribes to a hospital for cripples, he doesn't want his money to go to a foundling hospital. Now that I know that we are going to have a physical department, you can have my subscription at any moment."

The discussion that followed showed that there was a diversity of opinion as to the effect of action previously taken, though all speakers agreed that the intention was to secure by the Alumni Building Fund the erection of laboratories for chemistry and physics. To remove the possibility of misunderstanding it was, upon motion of Mr. A. C. Humphreys, "*Resolved*, That all funds collected under the present plan of Alumni Building Fund shall be

first applied to the erection of a building or buildings for the departments of chemistry and physics."

On motion of Mr. Hart it was resolved to lay upon the table the resignations of Mr. Albert Spies and C. W. Thomas.

The President called on Mr. Renwick for a report from the committee having in charge the constitution and by-laws.

Mr. Renwick suggested that the proposed constitution, which had been printed and distributed, be read, section by section, and that discussion be had upon it.

After an animated, and quite general, discussion as to the action the meeting should take concerning the proposed constitution, the majority appearing to consider that the printed copies had not been distributed early enough for proper examination, the following resolution was adopted—viz.: "*Resolved*, That one of "the members of the Committee who drew up this constitution be "requested to read it to us, and enlarge upon it briefly, and that it "be then discussed as far as the time will permit, and, finally be "referred to a special committee."

After the proposed constitution had been read by the Recording Secretary it was, upon motion of Mr. Kierman, "*Resolved*, That "the constitution be referred to a special committee of five "members to be appointed by the chair, and that it shall have "printed and mailed to each member of the Association copies "of any amendments proposed at least 30 days before the next "meeting."

The President stated that a communication had been received from the undergraduates in reference to the appointment of an alumnus as chairman of the "Senate" which they had organized.

On motion of Mr. Kierman the matter was referred to the Executive Committee, with power to act in conjunction with the Faculty.

On motion of Mr. Idell the thanks of the meeting were tendered to the sub-committee of the Executive Committee for their work in preparing the proposed constitution.

The meeting then adjourned, and the members repaired to the refreshment room, where the committee in charge had well provided for their entertainment.

MEMBERS IN ATTENDANCE.

President Henry Morton.
Prof. A. M. Mayer.
" De Volson Wood.
" J. Burkitt Webb.
" C. W. MacCord.
" A. R. Leeds.
" J. E. Denton.
" Wm. E. Geyer.
" T. B. Stillman.
Ass't Prof. A. Riesenberger.
" Wm. H. Bristol.
" S. D. Graydon.
" Robt. M. Anderson.
" Geo. L. Manning.
J. M. Cremer, '76.
G. C. Henning, '76.
Wm. Kent, '76.
P. E. Raque, '76.
A. P. Trautwein, '76.
A. R. Wolff, '76.
F. E. Idell, '77.
E. H. Kierman, '87.
J. A. McElroy, '87.
W. E. Parsons, '87.
A. H. Schlesinger, '87.
H. A. Bang, '88.
R. Beyer, '88.
N. H. G. Campbell, '88.
Geo. Dinkle, '88.
P. Doty, '88.
J. V. L. Pierson, '88.
Geo. H. Stueck, '88.
J. Eastwood, '89.
P. C. A. Graupner, '89.
D. H. Gildersleeve, '89.
F. Gubelman, '89.
Wm. D. Hoxie, '89.
E. L. McBurney, '89.
Geo. B. Muldaur, '89.
J. S. De Hart, Jr., '90.
C. J. Everett, '90.
Wm. Ebson, '90.
Wm. M. Farrar, '90.
L. H. Nash, '77.
O. Antz, '78.
Wm. Sheldon, '78.
W. W. Dashiell, '79.
E. S. Cronise, '81.
A. C. Humphreys, '81.
J. Wetzler, '82.
L. C. Dawes, '83.
F. C. Fraentzel, '85.
M. McNaughton, '83.
J. A. Bensel, '84.
E. H. Foster, '84.
Wm. L. Lyall, '84.
D. H. Maury, '84.
H. F. Mitchell, '84.
E. B. Renwick, '84.
J. M. Rusby, '85.
C. J. Field, '86.
Robt. M. Bayles, '87.
J. H. Cuntz, '87.
B. F. Hart, Jr., '87.
D. C. Harvey, '90.
A. B. Moore, '90.
E. H. Peabody, '90.
F. B. Stevens, Jr., '90.
E. H. Whitlock, '90.
Hugh Wreaks, '90.
A. P. Boller, '91.
J. A. Davis, '91.
Alex. Dow, '91.
J. M. Hanson, '91.
F. A. Muschenheim, '91.
L. H. Nettleton, '91.
J. A. Norcross, '91.
F. N. Sanborn, '91.
H. W. Smith, '91.
H. B. Atkins, '92.
H. T. Gurney, '92.
H. Harrison, '92.
Wm. O. Ludlow, '92.
K. L. Martin, '92.
C. F. Vogelius, '92.
H. D. Whitcomb, Jr., '92.

ATHLETICS.

THE ANNUAL CONVENTION of the Intercollegiate Athletic Association was in session at the Fifth Avenue Hotel, New York, from 2.30 till 6 P. M., February 25, 1893. Stevens was represented by Messrs. M. E. Craft. H. F. Cuntz. and W. H. Corbett.

A most important decision was reached—viz., not to abide by the "undergraduate rule," which has occasioned so much disturbance. Brown and Wesleyan were admitted to membe ship.

R. B. Wade, of Yale, was elected President.

BASE-BALL.—The Stevens Institute Athletic Association, at its annual meeting, decided to recognize and advocate a base-ball team for 1893.

Mr. Paulsen has been selected as Captain, Mr. Merkel as Manager, and Mr. Montgomery, Assistant Manager.

The schedule of base-ball games arranged for is as follows:

April 19.....	Stevens *vs.*	Columbia.....	.....at Hoboken.
" 21.....	"	Manhattan College	" Hoboken.
" 26.....	"	Columbia.....	" New York.
May 3... ..	"	Rutgers.....	" Hoboken.
" 11.....	"	"	" New Brunswick.
" 13.....	"	West End.....	" Somerville.
" 17	"	Union.....	" Hoboken.
" 26	"	"	" Schenectady.
" 27.....	"	West Point.....	" West Point.

The first game of the season was played April 19 with the Columbia College team, Stevens winning by a score of 4 to 3.

LACROSSE.—The annual convention of the United States Intercollegiate Lacrosse Association was held in Philadelphia on February 18, 1893, in the parlors of the Athletic Club of the Schuylkill Navy. Johns Hopkins, Lehigh, and Stevens were represented.

Several changes in rules were made, the more important being the extension of the authority of referees.

The championship of '92 was formally awarded Stevens. Below is the schedule of games arranged for season of '93:

May 5.....	Cornell *vs.* Stevens.....	.....at Hoboken.
May 10.....	Princeton *vs.* Stevens.....	.....at Hoboken.
May 13.....	Lehigh *vs.* Stevens.....	.at Hoboken.
May 16.....	C. C. N. Y. *vs.* Stevens.....	.....at Hoboken.
May 20.....	J. H. N. *vs.* Stevens.....	....at Baltimore.
May 24.....	C. C. N. Y. *vs.* Stevens.....	.....at New York.

For the ensuing year Mr. W. H. Corbett has been selected as Manager; Mr. H. F. Cuntz, President; and Messrs. Kellog and Corbett, as delegates.

INSTITUTE NOTES.

THE INSTITUTE CALENDAR for 1893-1894 contains the following dates:

Suplementary Term.—Sophomore, Junior and Senior Classes: From Tuesday, June 27, 1893, to Saturday, July 22, 1893.

First Regular Term.—From Wednesday, September 27, 1893, to the Saturday before Christmas.

Public examination on the work of the term begins Monday, December 11, 1893.

Second Regular Term —From Wednesday, January 3, 1894, to Wednesday, March 21, 1894.

Public examination on the work of the term begins Monday, March 12, 1894.

Third Regular Term.—From Monday, April 2, 1894, to Wednesday, June 20, 1894.

Public examination on the work of the term begins Monday, June 11, 1894.

Commencement, Thursday, June 21, 1894.

ENTRANCE EXAMINATIONS will be held June 9 to 17, and September 18 to 25, in accordance with rosters published in the catalogue.

ARRANGEMENTS are being made by which the requirements for admission to the Freshman class in 1895 will be extended so as to include: Mathematics: Spherical Trigonometry; Wells' College Algebra, entire. Chemistry: Inorganic, Theoretical and General. Physics: Sound.—Deschanel. Belles-Lettres: History of the English Language.—Meiklejohn·

PROFESSOR KROEH's recent work, entitled "How to Think in French," has received the most flattering notice by leading educators. The Chancellor of Chautauqua writes:

"455 FRANKLIN STREET,
"BUFFALO, N. Y., March 21, 1893.

"MY DEAR SIR: You have done a great and beautiful work in the "publication of your manuals, 'How to Think in French,' 'The Pro-"nunciation of French' and 'The French Verb.' These little books should "have the widest circulation.

"JOHN H. VINCENT,
"Chancellor of Chautauqua."

Aiming to place before the English speaking race, the most simple, direct and effective method of acquiring the use of foreign languages, Pro-

fessor Kroeh has worked up the "Living Method," by which the student quickly learns to associate objects, actions, ideas and their relations with the words which represent them in the language under study; and thus to think directly in that language. A somewhat similar course has been advocated, and sometimes employed, for oral class instruction; but Professor Kroeh's book will greatly facilitate the study of French outside of the classroom, as well as within it. An interesting and valuable aid in the acquisition of correct pronunciation is provided by Professor Kroeh in a phonograph cylinder containing the exact pronunciation (by a Parisian) of the fundamental sentences of the book. Parties who have phonographs can thereby familiarize their ear to the correct sounds of the language at their own homes, and at a very moderate expense. Professor Kroeh has in preparation similar works for German, Spanish and Italian; and for the learning of English by Germans and by Spaniards. Already the first edition of "How to Think in French" has been exhausted.

ON THE INVITATION of Commodore Melville, Professor Denton will contribute to the International Congress, at the World's Columbian Exposition, a paper on the "Principal Steps in Steam Engine Economy."

PROFESSOR JACOBUS has been conducting an efficiency test of the steam plant at the Williamsburgh station of the Edison Illuminating Company. The two engines at this station are of the latest design for this class of work, and each is directly connected to two multipolar dynamos.

IN *The Steamship, A Scientific Journal of Marine Engineering*, published at Leith, England, appears a lengthy notice of Professor MacCord's "Mechanical Drawing," which must be highly gratifying to the author. The publication of Professor MacCord's work has already been announced in the INDICATOR.

THE A. J. Johnson Company has selected Professor Jacobus to contribute articles on "Ice" and "Refrigerating Machines" to Johnson's Universal Cyclopedia.

A SCHEME for the commercial analysis of hematite, limonite, specular and spatic iron ores, prepared by Dr. Stillman, and as used for instruction in his department, appeared in the February, sixth issue, of *Stevens Life*.

THE STEVENS PHOTOGRAPHIC SOCIETY held its fifth annual exhibition of slides and photographs in Stevens School hall February 6. Notwithstanding the unpleasant weather, the hall was comfortably filled. While the exhibit of photographs was not so large as in some previous years, the slides, of which there were about 150, were quite up to the standard and were explained and commented upon in a very pleasing manner by the President, Mr. E. R. Douglas.

Especially interesting slides were those of scenes in the Western States and Alaska, taken by Professor Jacobus last spring.

THE EXHIBIT of sketches by the Stevens Sketch Club was excellent, showing in the improvement of its work the usefulness of the club in developing the talent in this direction.

THE SECOND TERM is the term of the inspection trips and the Juniors and Seniors profited by a good programme this year. The first one was that of the Seniors with Professor Denton to The De La Vergne Refrigerating Machine Company's plant, foot of East One Hundred and Thirty-first Street, New York, on January 26, 1893. The whole class with a single exception was present and was treated collectively and individually by the De La Vergne people in a most hospitable manner.

The next day, February 27, Professor Denton went with the Juniors to visit the works in Brooklyn for the manufacture of the Whitehead torpedo.

ON FEBRUARY 15 the Seniors visited the Westinghouse Electric Company's works in Newark (formerly the U. S. Electric Company) with Professor Geyer. This trip was also taken by most of the members of the class, and proved to be very interesting and instructive.

A VISIT with Professor Denton, March 2, to see a De La Vergne refrigerating plant in operation at Ehret's brewery was enjoyed by a large number of the class.

THE NEW ENGLAND inspection trip was, of course, the best trip of the season to those who were able to go.

Sixteen members of the class participated in this trip, leaving Hoboken on the afternoon of March 3, and returning early Friday morning, March 10.

The following are among the places visited:

Holyoke Testing Flume, Holyoke; Dickinson Paper Mills, Holyoke; Holyoke Machine Works, Holyoke; Watertown Arsenal, Boston; Boston Sewage Pumping Station, Boston; West End Railway Power Station, Boston; Thomson-Houston Electric Company, Lynn; Massachusetts Institute of Technology; Hope Street Station, Providence; Pawtucket Water-Works, Pawtucket; The Brown & Sharp Manufacturing Company, Providence; The Harris-Corliss Steam Engine Company, Providence; Richard Borden Mills, Fall River; Globe Yarn Mills, Fall River.

THE ANNUAL Hoboken concert of the Glee and Banjo Clubs was given in the new Quartette Club Hall on the evening of February 20.

It was the aim of the clubs to give one of the best concerts ever given in Hoboken, and they did not fall far short of it. The new hall was certainly a great improvement upon the old Odd Fellows Hall where the concerts have previously been held.

An informal dance was given after the concert, which was enjoyed by many.

The concert was also a success financially, and the proceeds were devoted to the benefit of the Athletic Association.

Another very successful concert was given by the clubs in Bergen Point, March 7.

On account of the inability of some of the members to go the Eastern trip, which had been planned, was given up.

The Engineering Society held a very interesting meeting during the second term. Among the papers read were the following:

"The Latest Form of Typesetting Machine," by W. P. Mackenzie, '93, "Locomotive Construction," by R. E. Chandler, '93; "The Viscosity of Oils," by A. B. Lord, '93; "The Westinghouse Air Brake," by A. R Williams, '95; "Cotton Seed Oil," by B. A. Inglis, '93; "The Get Up of a Daily Newspaper," by E. B. Gallaher, '94.

The last three papers were illustrated by means of lantern slides. All of the papers were interesting in themselves, and were delivered in a very creditable and interesting manner by their authors.

While considerable practice in speaking is obtained in the class room it is not sufficient; and the value of such practice as obtained in presenting papers before the Engineering Society cannot be overestimated.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. Managing Editor.

'75.

Yokichi Yamada died last year in Tokio, Japan. He was Professor of Mechanical Engineering in the University of Tokio, which had conferred upon him the degree of Doctor of Engineering.

'76.

A. R. Wolff has removed his office from the Potter Building to Rooms 907, 908 and 909 Fulton Building, Fulton and Nassau Streets, New York City.

'77.

John Rapelje is Superintendent of the Gauley Coal Land Association, and is located at Alderson, W. Va.

F. E. IDELL has removed his office from 41 Dey Street to Room 616, Havemeyer Building, Cortlandt and Church Streets, New York City.

'78.

HARRY W. HAZARD, Vice-President of the Dunbar Furnace Company President of the Crane Iron Company and of the Radford Crane Iron Company, of Philadelphia, visited the Institute a short time ago.

'79.

WILLIAM W. DASHIELL has estalished a business under the name of W. W. Dashiell & Co., at 2 and 4 Stone Street, New York City, for the sale of motive power and machinery supplies, lubricating oils, and special compounds for manufacturing purposes.

'83.

JAMES E. SAGUE is the Mechanical Engineer of the Schenectady Locomotive Works, having accepted this position about a year ago.

'84.

WILLIAM L. LYALL has been promoted from Junior to full membership in the American Society of Mechanical Engineers.

HENRY S. PRENTISS has leased, for a term of years, the New York Rental Business of the Prentiss Calendar and Time Company, Nos. 48 and 50 Maiden Lane, New York City, and is General Manager of the company.

'85.

JOHN M. RUSBY has applied for full membership in the American Society of Mechanical Engineers.

'86.

GEORGE R. METCALFE is the editor of *Electricity*, a weekly magazine with publication office at 6 Park Place, New York City, and also in Chicago and Boston.

The issue of *Electricity* of April 19, 1893, contains an interesting article about the Institute.

WILLIAM R. KING is at present engaged in designing, erecting and contracting for mining plants in Florida. New York address is 126 Liberty Street, Florida address, Box 506, Ocala. Mr. King has been, until recently, Manager and Engineer of the Empire State Phosphate Company, Rock Mines, Fla.

'88.

JOHN V. L. PIERSON is connected with the Celluloid Company, 295 Ferry Street, Newark, N. J., and is in charge of the department, recently established, for the manufacture of veneering.

T. E. THEBERATH resigned his position as Chief Electrician of the U. S. Electric Light Company, at Newark, N. J., to take charge of the

alternating current specialties of the Electrical Supply Company, Randolph Street and Michigan Avenue, Chicago, Ill.

RICHARD BEYER was married on March 30 to Miss Caroline Augusta Rabe, of Hoboken, N. J.

LARZ W. ANDERSON resigned the Superintendency of the Addyston Works of the Addyston Pipe and Steel Company, of Cincinnati, on the first of the year, and is now Treasurer of the J. A. Fay & Egan Company, of the same city.

C. G. RICHARDSON is connected with The George F. Blake Manufacturing Company, 163 South Canal Street, Chicago, Ill.

THORBURN REID is an Engineer in the Calculating Department of the Thomson-Houston Factory of the General Electric Company at Lynn, Mass.

WILLIAM WHIGHAM is draughting for the Carnegie Steel Company at Homestead, Pa.

'89.

A. G. MAYER has a paper in the April number of *The American Journal of Science*, describing his experiments, and stating the results of his research relating to "The Radiation and Absorption of Heat by Leaves."

'90.

J. T. WESTCOTT has left the employ of the United Gas Improvement Company, of Philadelphia, to become General Manager and Treasurer of the Economical Gas Apparatus Construction Company, of Toronto, Ont. Address 203 Yonge Street, Toronto, Canada.

A. R. WHITNEY, JR., is General Manager of the Puget Sound Wire Nail and Steel Company, and Manager of the Everett Railway and Electric Company. The latter company is operating an arc and an incandescent plant and three lines of electric railroad at Everett, Washington.

FREDERICK N. CONNET is the Chief Draughtsman of the Builders' Iron Foundry, Providence, R. I., and as assistant to Mr. A. A. Fuller, '88, Superintendent of Machine Shops, is employed in designing considerable special machinery.

'91.

L. E. ELSON has become a member of the American Society of Mechanical Engineers.

FREDERICK T. GAUSE has applied for full membership in the American Society of Mechanical Engineers.

'92.

NICHOLAS S. HILL, JR., is Inspecting Engineer for the South Side Rapid Transit Railroad Company, No. 627 The Rookery, Chicago, Ill.

WILLIAM ORR LUDLOW has been elected to Junior membership in the American Society of Mechanical Engineers.

H. LÖWENHERZ is employed in the testing laboratory of the Westinghouse Electric and Manufacturing Company, at Newark, N. J.

E. D. LITCHFIELD has accepted the position of Superintendent of Works of the Philadelphia Car Wheel Company, corner Snyder Avenue and Swanson Street, Philadelphia, Pa.

OSCAR C. WHITNEY was married to Miss Jessie E. Clark on November 30.

'93.

F. D. FURMAN has been appointed instructor in the sketching department of mechanical drawing at the Institute.

THE STEVENS INDICATOR.

VOL. X. JULY, 1893. No. 3

THE CHEMICAL AND PHYSICAL EXAMINATION OF PORTLAND CEMENT.

BY PROF. THOMAS B. STILLMAN.

THE enlarged consumption of Portland cement in this country during the past few years has caused the subject of its chemical and physical properties to receive increased consideration. Not only has the consumer been directly interested that the cements used should stand specified tests, but the attention of the manufacturer has been drawn in the same direction, resulting in improvements in methods of production. While the Portland cement manufacture here is yet in its infancy, with a history of practically less than ten years, its product for 1891 reached a total of 450,000 barrels, out of 3,500,000 barrels consumed in this country during that year.

This ratio between home production and importation will be radically changed in the near future, since the product for 1892 was over 600,000 barrels. A number of causes have prevented the use of American Portland cements in the home market, one of the chief of these being that the imported German cements always gave higher physical tests when made by the German methods of testing, than the American cements under the American system of testing.

A number of American Portland cements are fully as good as the best German cements, and have shown fully as high tensile strength when tested by the same methods.

These differences in results are not due entirely to the cements, but rather to the methods in use in the different countries for test-

Weigh out two grammes of the finely-pow
[illegible]-liter flask, wash well, make solution up to con

) *Residue:* Dry, ignite, fuse in platinum crucible [illegible] Na_2CO_3. Cool, dissolve in water, acidify with [illegible]Cl; evaporate to dryness in 4-inch porcelain cap[illegible]; take up with HCl and water, boil, filter and [illegible]wash.		(2) *Solu*
		(3) *Resi* in sil
[illegible]*idue:* SiO_2. Dry, ignite [illegible]nd weigh as SiO_2.	*Solution:* Make alkaline with NH_4HO; warm, filter, wash (neglect filtrate). Residue is Al_2O_3. Dry, ignite and weigh as Al_2O_3.	*Residu* weig weig differ
[illegible]t. of $SiO_2 \times 100$ / 2 = % SiO_2	Wt. of $Al_2O_3 \times 100$ / 2 = % Al_2O_3	Wt. of
Crucible + SiO_2 = 11.205 grammes. Crucible = 10.721 SiO_2 = .484 $\frac{.484 \times 100}{2}$ = 24.20 % SiO_2	Crucible + Al_2O_3 = 10.743 grammes. Crucible = 10.721 Al_2O_3 = .022 $\frac{.022 \times 100}{2}$ = 1.10 % Al_2O_3.	
SiO_2.	Al_2O_3.	
+	+	

* Manganese oxide is seldom found in Portland cemen
[illegible]MnO_2 filtered off and the filtrate treated as directed in (4).

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NY

The following well-known brands of Portland cements were analyzed, in my laboratory, by above method:

	Burham's.	Dyckerhoff's.	Saylor's.
SiO_2	21.70 per cent.	19.05 per cent.	21.25 per cent.
Al_2O_3	6.82 "	7.90 "	4.21 "
Fe_2O_3	2.37 "	5.38 "	8.25 "
CaO	62.26 "	63.62 "	61.25 "
MgO	1.48 "	1.87 "	1.50 "
K_2O	1.84 "	0.88 "	1.01 "
Na_2O	0.98 "	0.36 "	0.99 "
SO_3	1.20 "	0.94 "	1.38 "
CO_2	1.30 "	.....	.....
	99.95 "	100.00 "	99.84 "

In some cements quartz is a constituent in amounts varying from 0.5 to 6 per cent. It can be separated from combined silica by the method of Fresenius (*Quant. Chem. Anal.*, p. 259).

Where carbonic acid has been indicated by the qualitative analysis, the quantitative analysis should be made upon at least eight grammes of the cement.

The carbonic acid rarely reaches 1 per cent., and while it is generally absent in well-burned cements, it is by no means an uncommon constituent to the amount of 0.15 to 0.30 per cent., as the following table of analysis of German cements will show:*

	1	2	3	4	5	6	7	8
CaO	61.99	62.89	63.71	63.27	65.59	59.96	64.51	60.81
SiO_2	23.69	22.80	25.37	19.80	22.85	23.70	22.38	22.63
Fe_2O_3	2.71	3.40	3.14	3.22	2.76	3.15	2.24	2.42
Al_2O_3	8.29	7.70	4.31	6.73	5.51	8.20	9.45	7.06
MgO	0.47	1.20	1.25	2.02	1.24	1.00	.....	2.89
Alkalies	0.95	1.30	0.84	1.48	0.92	1.05	.....	2.83
SO_3	0.69	0.71	0.87	1.08	1.69	0.88	1.44	0.47
CO_2	0.27	.....	.....	0.23	.....	0.26	.....	0.33
Insoluble	0.44	.....	.....	1.38	.....	0.80	.....	.....

* *Der Portland-Cement und seine Anwendungen im Bauwesen*, Berlin, 1892, page 18.

THE MECHANICAL TESTING.

The method recommended for use in this country by the American Society of Civil Engineers, is as follows:

First. Determination of fineness.

Second. Liability to checking or cracking.

Third. Tensile strength.

FINENESS.

Tests should be made upon cements that have passed through a No. 100 sieve (10,000 meshes to the square inch), made of No. 40 wire, Stubb's wire gauge. The finer the cement, the more sand it will unite with, and the greater its value.

LIABILITY TO CHECKING OR CRACKING.

Make two cakes of neat cement 2 or 3 inches in diameter, about one-half inch thick, with thin edges. Note the time in minutes that these cakes, when mixed with mortar to the consistency of a stiff plastic mortar, take to set hard enough to stand the wire test recommended by General Gillmore—viz., one-twelfth inch diameter wire loaded with one-fourth pound, and one twenty-fourth inch diameter wire loaded with one pound. One of these cakes, when hard enough, should be put in water, and examined from day to day, to see if it becomes contorted, or if cracks show themselves at the edges; such contortions or cracks indicating that the cement is unfit for use at that time. In some cases, the tendency to crack, if caused by too much lime, will disappear with age. The remaining cake should be kept in the air, and its color observed, which, for a good cement should be uniform throughout.

TENSILE STRENGTH.

One part of the cement should be mixed with three parts of sand, for the seven days and upward test, in addition to the trials of the neat cement.

The proportions of cement, sand and water should be carefully determined by weight; the sand and cement mixed dry, and all the water added at once.

The mixing must be rapid and thorough; and the mortar, which should be stiff and plastic, should be firmly pressed into the molds with the trowel without ramming, and struck off level; the molds, in each instance, while being charged and manipulated, to be laid directly on glass, slate or other non-absorbent material The molding must be completed before incipient setting begins.

As soon as the briquettes are hard enough to bear it, they should be taken from the molds, and kept covered with a damp cloth, until they are immersed. For the sake of uniformity, the briquettes, both of neat cement and those containing sand, should be immersed in water at the end of 24 hours, except in the case of one-day tests.

Ordinary clean water, having a temperature between 60° Fahr. and 70° Fahr., should be used for the water of mixture and immersion of sample.

The proportion of water required is approximately as follows:

For briquettes of neat cement, about 25 per cent.

" " " { 1 part cement, } about 15 per cent. of total
{ 1 part sand, } weight of cement and sand.

" " " { 1 part cement, } about 12 per cent. of total
{ 3 parts sand, } weight of cement and sand.

The object is to produce the plasticity of rather stiff plasterer's cement.

An average of five briquettes may be made for each test, only those breaking at the smallest section to be taken. The briquettes should always be put in the testing machine and broken immediately after being taken out of the water, and the temperature of the briquettes and of the testing room should be constant, between 60° Fahr. and 70° Fahr.

The following table shows the average minimum and maximum tensile strength per square inch which some good cements have attained.

AMERICAN AND FOREIGN PORTLAND CEMENTS. NEAT.

One day, one hour or until set, in air, the rest of the 24 hours in water—from 100 to 140 pounds per square inch.

One week, one day in air, six days in water, from 250 to 550 pounds per square inch.

One month, (28 days), one day in air, 27 days in water, from 350 to 700 pounds per square inch.

One year, one day in air, the remainder in water, from 450 to 800 pounds per square inch.

AMERICAN AND FOREIGN PORTLAND CEMENTS. 1 PART OF CEMENT TO 3 PARTS OF SAND.

One week, one day in air, six days in water, from 80 to 125 pounds per square inch.

One month (28 days), one day in air, 27 days in water, from 100 to 200 pounds per square inch.

One year, one day in air, the remainder in water, from 200 to 350 pounds per square inch.*

* In regard to modification of these conditions required for tensile strength consult *Transactions* American Society of Civil Engineers, August, 1891, page 285.

Within the limits given, the value of a cement varies closely with the tensile strength when tested with the full dose of sand.

The machines for determining the tensile strength of Portland cements in use in this country are the "Fairbanks," Fig. 1, and the "Riehle," Fig. 2.

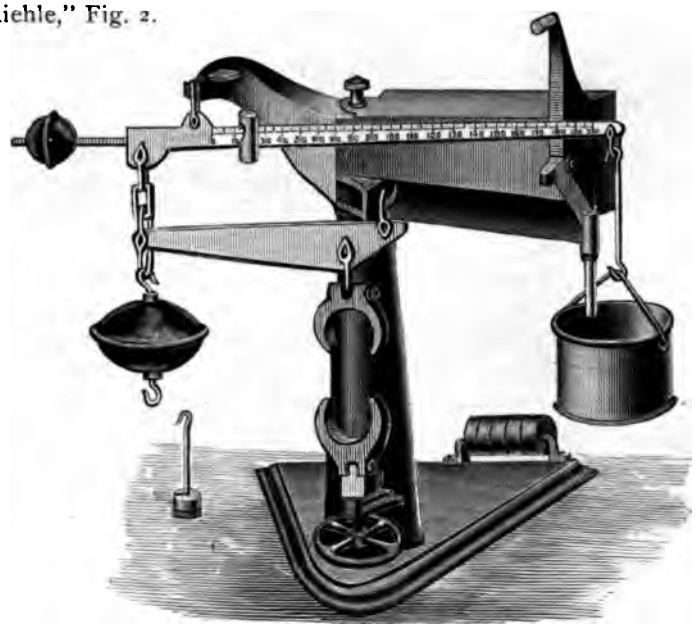

FIG. 1.

The Fairbanks machine is automatic, and is operated as follows: Hang the cup on the end of the beam. See that the poise is at the zero mark, and balance the beam by turning the ball.

Place the shot in the hopper; place the briquette in the clamps, and adjust the hand wheel so that the graduated beam will be inclined upward about 45 degrees. Open the automatic valve so as to allow the shot to run slowly. When the specimen breaks, the beam drops and closes the valve through which the shot has been pouring. Remove the cup with the shot in it, and hang the counterpoise weight in its place. Hang the cup on the hook under the large balance ball, and proceed to weigh the shot, using the poise on the graduated beam and the weights on the counterpoise weight.

The result will show the number of pounds required to break the specimen.

The "Riehle," while not automatic, is accurate, and responds to differences as slight as 1 pound in 2,000. The distinctive features are:

(*a*) The poise moves quietly and smoothly on the weighing beam.

(*b*) The weighing beam is long, and the marks not too close together. The slightest movement of the beam is promptly and plainly indicated by the motion of the pointer.

FIG. 2.

(*c*) The levers are tested and sealed to U. S. standard weight.

(*d*) The arrangement of the "grips" to hold the briquettes is such that they are always swung from pins, thus giving the test upon the cement when the briquette is "on a dead straight line."

Directions for testing Portland cement, according to the Official German Rules.*

The quality of a mortar made with cement depends not only on the strength of the cement itself, but also on the degree of subdivision of the same. It is, therefore, necessary to make the test

* *Portland Cement*, by Gustav Grawitz.

both with neat cement and with a mixture of the same with "standard sand." This latter, as used at the Royal Testing Station at Berlin, is produced by washing and drying quartz sand, which must be clean as possible, and afterwards be sifted through a sieve of 60 meshes per square centimeter (387 meshes per square inch), by which process the coarsest particles are separated. The sand is again sifted through a sieve having 120 meshes to the square centimeter (774 meshes per square inch).

The residue remaining in this sieve is the "standard sand" for experiments, the coarsest and finest particles having been eliminated. It is absolutely necessary, in order to obtain uniform results, to use only the "standard sand," as the size of the grain has a material influence on the results of the testing. The sand must be clean and dry, and all earthy and other substances previously removed by washing.

PREPARATION OF BRIQUETTES OF NEAT PORTLAND CEMENT.

Upon a slab of metal or marble are laid five sheets of filtering paper, which have been previously saturated with water, and upon these are placed five brass molds (Fig. 3), thoroughly clean and moistened with water; 1,000 grammes of cement and 250 grammes

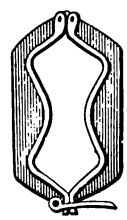

FIG. 3.

of water must be thoroughly mixed, well worked up, and when the resulting mass has been rendered perfectly homogeneous, it is poured into the molds. The latter must be gently tapped, by means of a wooden hammer, with equal force on both sides, during 10 to 15 minutes, to insure the escape of confined globules of air.

The molds must be carefully filled up until the mass becomes plastic. The superfluous mortar is then struck off, and the mold carefully withdrawn. The samples, after remaining 24 hours exposed to the air, at a temperature of about 60° Fahr., must be immersed in water having the same temperature, and care must be taken that they remain covered with water until the time arrives

for breaking them. In order to obtain a proper average, at least ten briquettes should be prepared for every examination.

PREPARATION OF BRIQUETTES FROM A MIXTURE OF PORTLAND CEMENT AND STANDARD SAND.

Place the molds on metal, as described in preparation of neat cement briquettes. The quantities (by weight) specified of cement and sand are thoroughly mixed, and to this is added the requisite quantity of water. The whole mass is then worked up with a trowel or spatula until it becomes uniform. In this manner is obtained a very stiff mortar. The molds are filled, and mortar heaped up; the latter is then beaten into the molds with an iron trowel, at first lightly, and afterwards more heavily, until it becomes

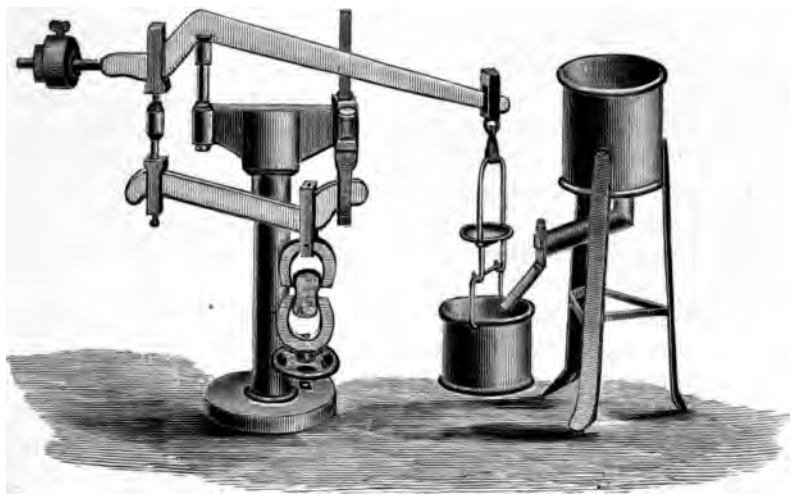

FIG. 4.

elastic, and water appears on the surface. The superfluous mortar is then scraped off with a knife, and by means of the same the surface is leveled. The further treatment of these briquettes is the same as for neat cement briquettes. The average of ten breaking weights furnishes the strength of the mortar tested.

The machine in general use in Germany for determining the tensile strength of cements is the "Michaelis" (Fig. 4), and from this is derived, with modifications, the "Reid and Bailey" machine in use in England, and the "Fairbanks," previously described.

(TO BE CONTINUED.)

INVESTIGATION OF THE LOSSES OF PRESSURE OF COMPRESSED AIR AND OF STEAM IN PIPES.*

(CONCLUDED.)

BY CH. LEDOUX,

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PROFESSOR AT L'ECOLE SUPERIEURE DES MINES.

II. LOSS OF PRESSURE OF STEAM.

THE loss of pressure of steam in pipes is much more difficult to determine than that of compressed air, because of the presence of a new element, of which it is necessary to take account—namely, the condensation produced by external cooling. In the case now under consideration, the loss of energy arises from two causes, distinct, yet contributing to the same result:

1. The cooling due to the conductivity of the pipes.

2. The loss of pressure due to the friction of the fluid upon the interior surfaces.

The first cause becomes apparent by a diminution in the volume of gas; the second, by a lessening of the pressure.

According to M. Chrétien,† who has made numerous experiments upon this subject, the cooling of steam in pipes depends upon its temperature, upon the surrounding temperature, upon the metal of the pipes, and upon the nature of the medium in which they are situated.

It depends also upon the conductivity of the covering and upon the manner in which the pipes are laid.

Thus, a steam pipe surrounded by water gives more condensation for the same temperature than if it were surrounded by air. Dry air cools less than moist air; still air, less than air in motion, etc. For equal exterior surfaces, small diameters produce greater

* Extract from *Annales des Mines*, Nov., 1892. Translated from the French by S. D. Graydon.

† *Le transport de la vapeur à de grandes distances et sa constitution*, par J. Chrétien, ingénieur civil, Baudry, éditeur, 1885.

condensation than large ones, and horizontal pipes more than those which are vertical. When steam is admitted into a cold pipe, the condensation, very considerable at first, gradually diminishes, until the whole pipe throughout has acquired its normal temperature.

The condensation then becomes a little more regular, the normal temperature not being attained until after a time, which depends upon the pipes themselves, and upon the coverings. The metal itself is very rapidly heated by reason of its great conductivity; the coverings, on the contrary, heat up more slowly, requiring greater time according as they are more efficient.

M. Chrétien's tests show that pipes acquire their normal temperature in about from five to ten minutes, according to the temperature of the external air; while well covered pipes do not attain to it, until after the expiration of about eighty-five minutes.

The pressure or temperature of the steam also exerts a sensible influence upon condensation.

The following, are the figures furnished by M. Chrétien for a wrought-iron steam pipe, nearly horizontal, 66 millimeters in inside diameter, 6 millimeters thick, and 26.04 meters long.

TABLE V.—*Steam Condensed per Hour, and per Square Meter of Exterior Surface.*

Effective Pressures in Kilogrammes per Square Centimeter.	Absolute Pressures in Atmosphere.	Uncovered Pipes. Kilogrammes.	Well Covered Pipes. Kilogrammes.
1	1.968	2.72	0.387
2	2.935	3.11	0.455
3	3.903	3.43	0.501
4	4 870	3.66	0.536
5	5.838	3.89	0.570
6	6 806	4.10	0.600
7	7.773	4.30	0.627
8	8.741	4.43	0.653
9	9.710	4.63	0.676
10	10.677	4.77	0.697
11	11.645	4.91	0.716
12	12.612	5.05	0.735
13	13.580	5.12	0.754
14	14.547	5.23	0.773
15	15.515	5.40	0.790
16	16 482	5.51	0.806
17	17 450	5.62	0.823
18	18.417	5.78	0.839
19	19.385	5.83	0.854
20	20.353	5.88	0.869

If it is desired to refer the condensation to the square meter of *interior* surface, which is more rational, the above figures should be multiplied by the ratio $\frac{.78}{.66}$ or 1.18.

After making this correction, it appears from the figures of this table, that the condensation per hour and per square meter of *interior* surface, in well covered pipes, is very well represented by the formula $\gamma = .375 \sqrt[3]{p}$, in which p is given in atmospheres.

The condensation increases therefore with the pressure. On the other hand, the diameter of pipe required to deliver a given weight of steam, decreases according as the pressure increases.

It is easily shown, that, within the limits of pressure which ordinarily obtain, there is some advantage, considered in reference to the quantity of steam condensed, in using high pressures, which admit of reducing the diameter.

Professor Gutermuth has made very careful experiments at the Josepha shaft of the Gehrard mine (bassin de Sarrebrück) upon the condensation and the loss of pressure of steam in pipes.* They were made upon two covered pipes placed side by side in the shaft, and supplied alternately with steam from several pumps located at a depth of 239 meters.

One of these cast-iron pipes had for the portion experimented with a length of 323 meters and an inside diameter of 140 m.m. The other in wrought iron was 330 meters long and 75 m.m. in inside diameter.

Below are the results given by the author for steam at rest:

TABLE VI.

Steam Pressure. Atmospheres.	CONDENSATION PER HOUR AND PER SQUARE METER OF THE INSIDE SURFACE OF PIPES.	
	Cast-Iron Pipes. 0.140 m. Diameter.	Wrought-Iron Pipes. 0.75 m. Diameter.
3	1.03	1.10
4	1.09	1.21
5	1.21	1.29
6	1.33	1.35

* Ueber die zweckmässigste Dampfgeschwindigkeit in Dampfleitungsröhren, von M. F. Gutermuth, *Zeitschrift des Vereines der deutschen Ingenieure*, n° 32, aout 1887.

These figures are nearly double those given by M. Chrétien. The difference arises from the manner in which the coverings were applied, and from the conditions of situation of the tested pipes.

In the experiments at Anzin, of which I will speak hereafter, an intermediate figure, .800, was found.

M. Chrétien has established, by a great number of experiments with those of different thicknesses and under pressures varying from 1 to 12 atmospheres, the value of various non-conductors employed in the arts.

Considered in reference to non-conductivity of heat, which is the principal quality sought, the different substances are classed as follows:

Plaits and pads made from the waste of silk head the list. Then follow with nearly the same quality, the waste from sponges, then felt of light hair. Tar paper or wrapping paper, plaits of straw, of seaweed and of rushes, differ but little from the above substances. Mineral wool, or wool of slag, cork and pulverized coke rank among the average good non-conductors. Wood and asbestos are not so good; finally, it is necessary to place in the lowest line under this head and with varying qualities the different plasters, mastics, or cements called non-conductors which present among themselves very perceptible differences.

M. Chrétien recommends the following covering as one of the most economical, as well as most effective.

Commence by pasting on the bare pipe three or four turns of heavy tar paper which will make a thickness of 1 to 2 millimeters, or else a layer of paper paste. This first coating, if it is well matted, is nearly incombustible, and of unlimited durability; it is chiefly intended to preserve the other enveloping layers from the carbonizing which rapidly occurs without it. Upon this first covering is rolled a single ring of plaits of rush, then a second, and then a third. Thus a covering 40 m.m. thick is obtained. In order to better confine the air enclosed in the mass of the envelope, a casing is put on which is made by pasting over the plait three or four turns of tarred paper. This case, in drying, becomes very durable. When pipes thus covered are exposed to moisture it is well to give the casing a coat of paint or of tar to protect it. If they are exposed to the rain, it is necessary, besides, to surround the pipes with zinc or galvanized sheet iron to thoroughly protect them.

It may be asked if the condensation is the same when the steam is in a static condition in the pipes, and when it moves with a greater or less velocity. This question remains in doubt. It appears, nevertheless, to result from the tests of M. Gutermuth and from those at Anzin that the condensation is practically the same in both cases.

Let us now seek to calculate the loss of pressure due to the flow of steam in a pipe with an inside diameter D and length L. Call m_0 the weight of steam, assumed to be dry, admitted per second to the entrance of the pipe.

The weight of steam m, which circulates about any point situated at a distance l from the entrance, will be:

$$m = m_0 - \gamma \frac{\pi D l}{3600} = m_0 - .000872\, \gamma\, D\, l \ldots\ldots (10)$$

γ being the weight of steam condensed per hour and per square meter of interior surface of the pipe.

At the end of the pipe the weight of steam available will be: $m_0 - .000872\, \gamma\, D\, L$.

Let p_0 be the initial absolute pressure of the steam, p the absolute pressure at a point of the pipe situated at a distance l from the mouth; p and p_0 are expressed in atmospheres.

We assume that the loss of pressure will be, as in the case of compressed air, proportional to the density δ of the gas in motion, to the square of the velocity, to the length passed over, and inversely to the diameter.

The fluid in motion is a mixture of steam and of water, the latter arising from the condensation which has occurred from the entrance along the length l. The weight of this fluid is m_0; its volume is practically equal to that of the steam, the volume of accompanying water being insignificant in comparison with that of the steam.

The density of steam is known to be equal to $.606\, p^{.94}$ when p is given in atmospheres; and to $.588\, p^{.94}$ when p is given in kilogrammes per square centimeter.

The volume of the weight m of steam is therefore

$$v = \frac{m}{.606\, p^{.94}} = \frac{m_0 - .000872\, \gamma\, D\, l.}{.606\, p^{.94}}$$

The density δ of the mixture m_0 of steam and water is:

$$\delta = \frac{m_0\ .606\, p^{.94}}{m} = \frac{m_0\ .606\, p^{.94}}{m_0 - .000872\, \gamma\, D\, l}$$

The velocity of the fluid $= \frac{4\,v}{\pi\,D^2} = \frac{4\,(m - .000872\,\gamma\,D\,l)}{\pi\,D^2\,.606\,p^{.94}}$.

For differential increment $d\,l$ of the length of the pipe the loss of pressure will be:

$$10334\,dp = -K\,\frac{m_0\,.606\,p^{.94}}{m_0 - .000872\,\gamma\,D\,l}\cdot\frac{16\,(m_0 - .000872\,\gamma\,d\,l)^2}{\pi^2\,D^5\,.606^2\,p^{2.94}}$$

or

$$10334\,dp = -\frac{16\,K\,m_0\,(m_0 - .000872\,\gamma\,D\,l)}{\pi^2\,D^5\,.606\,p^{.94}}\,d\,l.$$

or

$$p^{.94}\,dp = -\frac{.0002589\,K\,m_0\,(m_0 - .000872\,\gamma\,D\,l)}{D^5}\,d\,l.$$

γ, in fact, is a function of p.

But, in order not to complicate the calculations beyond measure we will suppose γ constant and equal to the average of the values which correspond to p_0 and p respectively. Integrating between p_0 and p and between zero and L, we finally have:

$$p^{1.94} = p_0^{1.94} - \frac{.000502\,K\,m_0\,L}{D^5}\,(m_0 - .000436\,\gamma\,D\,L).....(11)$$

an equation which gives the pressure p at a point of the pipe situated at a distance L from the entrance.

If p and p_0 were expressed in kilogrammes per square centimeter, equation (11) would become:

$$p^{1.94} = p_0^{1.94} - \frac{.000535\,K\,m_0\,L}{D^5}\,(m_0 - .000436\,\gamma\,D\,L)...(11\tfrac{1}{2})$$

Experiments at Anzin.—The experiments conducted at Anzin were for the purpose of verifying the correctness of equation (11) and to determine the value of the coefficient of loss of pressure K.

They were made by M. Barry upon the same pipes which had been used with compressed air, at the Lambrecht moat.

One of the steam generators at the moat previously disconnected from the battery of boilers, was used to supply the current of steam. This generator consisted of two boilers and a reheater. The heating surface was 100 square meters; the grate surface 4.12 square meters. The outlet for the steam was 2 meters above the water level.

The measurement of the quantity of water evaporated in a given time, was made by means of the water glass.

The boiler was filled with cold water up to a mark upon the glass; water was added, and at every 50 liters a mark was made upon a band of paper pasted upon the glass.

It was thus possible to read the volume to 10 liters closely.

This volume was, moreover, corrected for the expansion of the water and of that of its sheet iron envelope.

Experiments were made upon three wrought-iron pipes, respectively of 100, 71 and 47 millimeters, inside diameter. These pipes were provided with a non-conducting covering, composed of a double wrapping of plaited straw, surrounded by tarred paper.

The pipe under test was connected with the boiler by about 60 meters of pipe, 100 millimeters in diameter unprotected, and having a general slope towards the boiler.

The pipe experimented upon, of which the lengths were:

For the 100 millimeter pipe, 305.8 meters.
" " 71 " " 304.9 "
" " 47 " " 303.6 "

had a general descent toward the free end.

A water separator was situated at the entrance of the pipe under test, and another at the other end.

The latter was closed by a stop-valve.

At the two extremities of the pipe at 4 or 5 meters from the separators, were two tubes with cocks to connect the gauges to.

Two other intermediate similar tubes divided the space into three nearly equal sections.

The boiler, being fired up and at a pressure a little greater than that which it was desired to have at the entrance, the valve at the end and the two waste cocks of the separators were opened.

The level of the water in the boiler was noted, the outlet valve was opened in such a way as to rapidly create a uniformity of flow; at the same time, the waste cocks of the separators were opened, and the water which issued during all the time of the test was caught in weighed receptacles.

The fireman managed the fire in such a way as to maintain the pressure at the boiler quite uniform. It was made certain by observing the gauges placed at the extremities of the pipe, that this course was maintained, and the pressures indicated by the gauges, were noted simultaneously at fixed intervals.

It was arranged to take four observations during the third of the duration of the test.

The gauge was then carried from the extremity to the tube situated at 200 meters from the entrance, and a series of four observations during the same lapse of time as for the first series was commenced. Finally, the gauge was again removed and set up at 100 meters from the origin, and four new observations were again made. It was then rapidly carried back to the end of the pipe, and, at an agreed signal, the valve at the end and the two waste cocks were simultaneously closed. It only remained to note the volume of water evaporated, the duration of the test, and the weight of water collected in each of the receptacles, in order to have all of the elements for the calculation of K in the equation:

$$K = \frac{(p_0^{1.94} - p^{1.94})\, D^5}{.000535\, L\, m_0\, (m_0 - .000436\, \gamma\, D\, L)} \quad \ldots\ldots (12)$$

The values of p and p_0 are indicated in the following tables, all corrections having been made.

Each of the values has been obtained by taking the average of four observations. Generally, these four figures were very close; exceptionally, the maximum variations of pressure reached 200 grammes.

The weights of water evaporated are similarly indicated, all corrections having been made. The water condensed per hour and per square meter of interior surface of the pipe in a state of rest was also determined. Five experiments were made upon the 100-millimeter pipe, the two first at a pressure of 3 kilogrammes, the three last at 6 kilogrammes. The water condensed per hour and for a surface of 97.64 square meters was

64.3 kilogrammes.
64.9 "
79.5 "
99.5 "
83. "

Average..... 77.44 kilogrammes, or .795 kilogrammes per hour and per square meter.

Upon the 71-millimeter pipe three tests were made; the two first at 3 kilogrammes, the last at 6 kilogrammes. The results are:

Water condensed per hour for a surface of 69.25 square meters:

56.7 kilogrammes.
58.7 "
52.7 "

Average..... 56.03 kilogrammes, or .809 kilogrammes per hour and per square meter.

Finally, five tests were made upon the 47-millimeter pipe, the first two at 3 kilogrammes, the three others at 6 kilogrammes. The water condensed per hour for a surface of 45.66 square meters was found to be:

68.1 kilogrammes.
70.1 "
80.1 "
93.1 "
93.1 "

Average..... 80.9 kilogrammes, or 1.8 kilogrammes per hour and per square meter.

The results obtained for the pipes of 100 and of 71 millimeters agree closely, and it appears that we may accept with confidence the figure 0.8 kilogrammes for the value of γ.

This is not true of those which the 47-millimeter pipe furnished, and which gave an average of condensation per hour and per square meter more than double the above figure.

On the other hand, if we examine the quantities of water collected in the second separator during the experiment on the loss of pressure, and arising from the condensation of steam in motion, we find that they vary greatly in the one test from the other, but their average gives results comparable among themselves and to those above.

Below are the figures reduced to the period of one hour:

100 m.m. Pipe.	71 m.m. Pipe.	47 m.m. Pipe.
65.5 kilog.	62. kilog.	33.9 kilog.
115.9 "	43.5 "	35 8 "
67.8 "	67.5 "	51.6 "
84.6 "	34.4 "	38.3 "
102.1 "	76.5 "	27.1 "
39.8 "	87.2 "	27.1 "
64.7 "	52. "	40. "
48.2 "	50.8 "	18.2 "
45.3 "	57.2 "	23. "
15.7 "	61.7 "	24.7 "
35.6 "	43.4 "	24. "
60.2 "	46.3 "	23.7 "
. . .	....	37.7 "
Average, 62.1 kilog.	Average, 56.8 kilog.	Average, 30.9 kilog.
whence $\gamma = \frac{62.1}{97.64} = .636$ kilog.	whence $\gamma = \frac{56.8}{69.25} = .820$ kilog.	whence $\gamma = \frac{30.9}{44.81} = .689$ kilog.

These figures are evidently the minima; for the separator does not remove all the condensed water, a part of the latter being entrained with the steam. They nevertheless seem to show, first, that the difference between the figure for condensation per hour and per square meter in the 100 and in the 71-millimeter pipes, and that of the 47-millimeter pipe, is not so great as the tests of condensation in the state of rest would appear to indicate; second, that the condensation of steam in motion does not differ much from that of steam at rest. Moreover, from the special point of view, of the determination of the coefficient of loss of pressure K, the uncertainty which exists as to the exact value of γ is of no practical importance.

As long as L is not very large, as was the case in the experiments at Lambrecht, the product $.000436\,\gamma\,D\,L$ remains very small; and the variation, even quite large, of the quantity γ influences but little up to the fifth decimal of the value of K: that is to say, that its influence is even less than that of experiment. Under these circumstances, there will be no objection to adopting for γ an average figure, the accuracy of which is only approximate. The values of K are none the less entitled to confidence. In the computation of the values of K which appear in the following tables, we have taken $\gamma =$ to .8 kilogrammes.

The results of thirty-six experiments made upon the 100 m.m. pipe agree very closely among themselves, and give for K an average of .00115. The same is true of the thirty-six experiments made upon the 71 m.m. pipe. Their average is .00118. Finally, the results of the experiments made with the 47 m.m. pipe, while all agreeing very closely among themselves, give a general average a little smaller..... .00094.

The final general average is..... .00107.

It is proper to observe that the causes of error conducing to falsify the results have a greater importance in the tests made upon the 47 m.m. pipe. In fact, the volumes of water evaporated in these tests are much smaller than in those of the two other series, and the relative importance of an error committed in the determination of entering weight m_0 is, in consequence, much greater.

This weight was obtained by deducting from the weight of water evaporated during the period of the test the weight of water collected in the first separator.

TABLE VII.—*Observations Made with a Pipe of 100 Millimeters Diameter.*

Lengths.	Absolute Pressures. At the Entrance. p_0.	Absolute Pressures. At the Exit. p.	Duration of Experiment.	Water. Evaporated by the Boiler.	Water. Collected at the Entrance.	Water. Collected at the Exit.	Weight of Steam Entering the Pipe per Second. m_0.	Velocity at the Entrance. u_0.	Values of K. Partial.	Values of K. Average.
Meters	Kilog.	Kilog.	M. Sec.	Kilog.	Kilog.	Kilog.	Kilog.	Meters		
305.8	5.508	3.528							0.00119	
203.3	5.478	4.308	40—15	2240.8	47.8	44	0.908	40.00	0.00114	0.00113
102.3	5.498	4.983							0.00105	
305.8	5.653	4.235							0.00108	
203.3	5.783	4.970	47—	2453.0	78.7	90	0.842	35.60	0.00099	0.00100
102.3	5.748	5.378							0.00092	
305.8	5.263	2.813							0.00101	
203.3	5.273	3.798	36—15	2288.0	34.4	41	1.036	47.10	0.00102	0.00100
102.3	5.240	4.583							0.00096	
305.8	5.168	3.080							0.00114	
203.3	5.088	3.893	40—	2217.0	30.0	56	0.911	42.15	0.00106	0.00114
102.3	5.178	4.518							0.00124	
305.8	5.083	4.000							0.00111	
203.3	5.073	4.435	42—25	1840.0	63.0	74	0.698	33.10	0.00102	0.00104
102.3	5.063	4.758							0.00098	
305.8	3.963	2.490							0.00114	
203.3	3.833	2.893	51— 5	2146.5	32.3	34	0.690	41.75	0.00111	0.00114
102.3	3.813	3.340							0.00117	
305.8	4.098	2.915							0.00103	
203.3	4.131	3.428	45—30	1887.0	48.5	49	0.673	38.85	0.00097	0.00096
102.3	4.058	3.740							0.00089	
305.8	4.015	2.248							0.00119	
203.3	4.098	3.995	40—35	1793.0	33.0	36	0.723	41.65	0.00125	0.00121
102.3	4.203	3.718							0.00120	
305.8	4.040	1.393							0.00125	
203.3	4.048	2.013	41—	1745.0	41.7	31	0.692	40.35	0.00127	0.00125
102.3	4.060	2.588							0.00123	
305.8	3.233	1.303							0.00105	
203.3	3.265	2.100	38—	1614.0	30.0	10	0.690	50.15	0.00121	0.00109
102.3	3.145	2.645							0.00101	
305.8	3.280	1.990							0.00166	
203.3	3.175	2.363	55—	1651.0	48.0	33	0.486	35.65	0.00163	0.00166
102.3	3.220	2.823							0.00169	
305.8	2.828	1.705							0.00115	
203.3	2.885	2.140	53—	1667.0	51.0	53	0.508	40.90	0.00123	0.00113
102.3	2.883	2.540							0.00131	

The general average = 0.00115.

TABLE VIII.—*Observations Made with a Pipe of 71 Millimeters Diameter.*

Lengths.	Absolute Pressures. At the Entrance. p_0.	Absolute Pressures. At the Exit. p	Duration of Experiment.	Water. Evaporated by the Boiler.	Water. Collected at the Entrance.	Water. Collected at the Exit.	Weight of Steam Entering the Pipe per Second. m_0.	Velocity at the Entrance. u_0.	Values of K. Partial.	Values of K. Average.
Meters	Kilog.	Kilog.	M. Sec.	Kilog.	Kilog.	Kilog.	Kilog.	Meters		
304.9	5.777	1.449							0.00104	
202.9	5.728	3.500	45—	1538	64	46.5	0.546	45.45	0.00101	0.00097
102.0	5.678	4.818							0.00087	
304.9	5.653	2.578							0.00121	
202.9	5.678	3.953	58—30	1698	96	42.5	0.456	38.40	0.00117	0.00110
102.0	5.703	5.075							0.00093	
304.9	5.953	4.060							0.00132	
202.9	5.978	4.875	71— 5	1745	135	80	0.377	30.30	0.00123	0.00116
102.0	5.918	5.513							0.00093	
304.9	4.930	1.475							0.00123	
202.9	4.955	3.068	58—10	1608	112	33	0.429	41.20	0.00121	0.00115
102.0	4.905	4.200							0.00102	
304.9	5.023	2.32							0.00130	
202.9	4.962	3.44	65—50	1689	137	84	0.393	37.40	0.00123	0.00120
102.0	4.968	4.360							0.00107	
304.9	5.073	3.268							0.00112	
202.9	4.917	3.858	69—25	1666	133	101	0.368	35.35	0.00103	0.00100
102.0	4.975	4.555							0.00086	
304.9	4.075	1.360							0.00132	
202.9	4.088	2.568	60—	1357	135	52	0.339	38.90	0.00133	0.00126
102.0	4.064	3.478							0.00113	
304.9	3.898	1.923							0.00110	
202.9	3.972	2.763	74—17	1557	94	65	0.328	38.90	0.00114	0.00103
102.0	3.956	3.54							0.00085	
304.9	4.039	2.640							0.00143	
202.9	4.013	3.130	86—	1457	113	82	0.260	31.00	0.00142	0.00134
102.0	4.003	3.648							0.00119	
304.9	3.068	1.508							0.00099	
202.9	3.078	2.090	72—40	1284	79	75	0.276	41.80	0.00104	0.00100
102 0	3.083	2.658							0.00096	
304.9	3.047	1.808							0.00119	
202.9	3.072	2.315	82—55	1247	93	60	0.232	35.70	0.00118	0.00112
102.0	3.062	2.755							0.00100	
304.9	3.093	2.153							0.00117	
202.9	3.050	2.473	100—10	1380	107	77	0.212	32.05	0.00111	0.00105
102.0	3.088	2.870							0.00087	

The general average = .00112.

TABLE IX.—*Observations Made with a Pipe of 47 Millimeters Diameter.*

Lengths.	Absolute Pressures.		Duration of Experiment.	Water.			Weight of Steam Entering the Pipe per Second.	Velocity at the Entrance.	Values of *K*.	
	At the Entrance. f_0.	At the Exit. f.		Evaporated by the Boiler.	Collected at the Entrance.	Collected at the Exit.	m_0.	u_0.	Partial.	Average.
Meters	Kilog.	Kilog.	M. Sec.	Kilog.	Kilog.	Kilog.	Kilog.	Meters		
303.60	3.325	1.570							0.00100	
202.75	3.211	2.183	76—10	594	95	43	0.109	35.75	0.00093	0.00093
101.30	3.208	2.768							0.00085	
303.60	3.168	2.128							0.00071	
202.75	3.093	2.425	82—30	566	51	71	0.104	35.10	0.00069	0.00068
101.30	3.063	2.755							0.00064	
303.60	3.122	1.693							0.00080	
202.75	3.117	2.178	79— 6	566	53	50.5	0.108	36.35	0.00086	0.00082
101.30	3.117	2.698							0.00081	
303.60	4.125	1.425							0.00086	
202.75	4.105	2.473	80—50	825.7	84	36.5	0.153	39.86	0.00089	0.00085
101.30	4.083	3.430							0.00079	
303.60	4.068	1.855							0.00084	
202.75	4.028	2.635	76—20	774	111	51	0.145	38.45	0.00087	0.00084
101.30	4.048	3.455							0.00081	
303.60	5.048	1.468							0.00099	
202.75	5.071	3.033	90—	1059	107	34.5	0.176	37.90	0.00102	0.00096
101.30	5.060	4.268							0.00089	
303.60	5.058	2.123							0.00088	
202.75	5.078	3.320	80— 5	941	89	36.5	0.177	38.15	0.00090	0.00086
101.30	5.083	4.370							0.00080	
303.60	6.045	1.510							0.00104	
202.75	6.028	3.523	80—35	1109	112	27.5	0.206	37.50	0.00106	0.00100
101.30	5.963	5.003							0.00091	
303.60	5.926	2.148							0.00101	
202.75	5.928	3.740	73—25	972	103	29	0.197	36.35	0.00102	0.00098
101.30	5.931	5.070							0.00091	
303.60	5.953	3.023							0.00097	
202.75	5.935	4.740	81—10	1014	106	?	0.186	34.50	0.00097	0.00094
101.30	5.940	5.070							0.00086	
202.75	3.117	1.913	90—20	690	142	54	0.101	34.05	0.00120	0.00117
101.30	3.129	2.605							0.00114	
202.75	4.078	2.348	70—45	669	68	32	0.142	37.25	0.00100	0.00108
101.30	4.093	3.378							0.00105	
202.75	5.063	2.888	72—30	827	89	22	0.170	36.50	0.00115	0.00109
101.30	5.053	4.193							0.00103	

The general average = .00094.

But this did not surely represent all of the entrained water. There was, moreover, a slight loss through the waste valve.

The figure thus calculated for m_0 was therefore too great; and the influence of this error, in the computation of K, was as much too great as m_0 was too small.

In view of the very remarkable agreement of the experiments upon the 100 and the 71 m.m. pipes, I think it proper to adopt for K the figure .0011.

It will be noticed that this value of K for steam is a little higher than that which was found for air.

In the memoir already cited M. Gutermuth gives the results of experiments upon the loss of pressure in two pipes; the one of wrought iron, .075 meter in diameter; the other of cast iron, .14 meter in diameter, located in a shaft.

Among the tables inserted in his memoir there are some which supply the elements necessary for the computation of K. I have reproduced them in the table below, and have calculated, in each case, the value of K, according to equation (11).

The pipes were located in a shaft. It was necessary to correct the final pressures by lowering the figures observed by the increase of pressure due to gravity. The values of γ were taken from Table VI.

TABLE X.—*Cast-Iron Pipe 323 Meters Long with Inside Diameter of 140 Millimeters.*

Initial Pressure. p_0.	Terminal Pressure Observed.	Increase of Pressure Due to Gravity.	Terminal Pressure Corrected. p.	Weight of Steam Supplied per Second. m_0.	Weight of Steam Condensed per Hour and per Square Meter. γ	Value of K.	Remarks.
2.99	2.84	0.039	2.801	0.585	1.02	0.00100	
4.00	4.01	0.050	3.960	0.397	1.09	0.00062	
3.00	2.87	0.039	2.831	0.573	1.02	0.00094	(*)
3.00	2.54	0.037	2.503	0.814	1.02	0.00128	

(*) Probably an error of observation.

NOTE.—The lower station was 239 meters below the surface.

The value of K supplied by the second experiment differed greatly from the others, and was supposed to be an error of experiment. If this observation be eliminated, the other numbers are found to agree closely, the general average being .00107.

TABLE XI.— *Wrought-Iron Pipe 330 Meters Long and 75 Millimeters in Inside Diameter.*

Observation.	Lengths of Pipes. L	Depth of the Section Below the Surface.	Initial Pressure Observed. p_0.	Terminal Pressure Observed.	Increase of Pressure Due to Gravity.	Terminal Pressure Corrected. p	Weight of Steam Supplied per Second. m_0.	Weight of Steam Condensed per Hour and per Square Meter. γ	Values of K.	Averages.
	Met.	Met.	Atm.	Atm.	Atm.	Atm.	Kilog.	Kilog.		
	130	100		2.63	0.01	2.62			0.00131	
A	230	200	2.96	2.47	0.03	2.44	0.221	1.05	0.00110	0.00119
	330	239		2.21	0.03	2.18			0.00115	
	130	100		3.83	0.02	3.81			0.00068	
B	230	200	3.88	3.70	0.04	3.66	0.162	1.19	0.00121	0.00100
	330	239		3.65	0.05	3.60			0.00111	
	130	100		5.47	0.03	5.44			0.00125	
C	230	200	5.89	5.06	0.07	4.99	0.361	1.31	0.00137	0.00132
	330	239		4.67	0.07	4.60			0.00134	
	130	100		4.55	0.03	4.52			0.00142	
D	230	200	5.78	3.53	0.05	3.48	0.538	1.22	0.00134	0.00133
	330	239		2.50	0.05	2.45			0.00122	
	130	100		4.72	0.03	4.69			0.00123	
E	230	200	5.78	3.95	0.05	3.90	0.545	1.21	0.00111	0.00118
	330	239		2.38	0.04	2.34			0.00120	
	130	100		4.68	0.03	4.65			0.00123	
F	230	200	5.76	3.55	0.03	3.52	0.546	1.21	0.00127	0.00121
	330	239		2.34	0.05	2.29			0.00121	
G	330	239	5.97	5.51	0.07	5.44	0.254	1.33	0.00123	0.00123
H	330	239	5.97	5.71	0.08	5.63	0.198	1.34	0.00132	0.00132
I	330	239	3.00	2.73	0.04	2.69	0.154	1.09	0.00110	0.00110

NOTE.—Some of the tests include observations at two intermediate stations.

The general average is .00121.

This is a little higher than for the .140-meter pipe. If the mean be taken between the two figures thus obtained for the two

pipes respectively—namely, .00107 and .00121, we have .00114, a value which approaches closely to that obtained from the experiments at Anzin. The agreement is indeed remarkable, and appears to me to be of a character to cause the acceptance with confidence of the definitive figure .0011.

The equation which gives the pressure at the end of a pipe of diameter D and length L for an initial weight of steam m_0 and an initial pressure p_0 is therefore

$$p^{1.94} = p_0^{1.94} - \frac{.000000552\ L}{D^5}\ m_0\ (m_0 - .000436\ \gamma\ D\ L)\ .(13)$$

if p and p_0 are expressed in atmospheres, and

$$p^{1.94} = p_0^{1.94} - \frac{.000000589\ L}{D^5}\ m_0\ (m_0 - .000436\ \gamma\ D\ L).(13\frac{1}{2})$$

if p and p_0 are expressed in kilogrammes per square centimeter.

If D is sought, the other quantities being known, the equation for D will be written, when p and p_0 are expressed in atmospheres:

$$(p_0^{1.94} - p^{1.94})\ D^5 + .000000000241\ \gamma\ m_0\ L^2\ D - .000000552\ m_0^2\ L = 0 \ldots\ldots\ldots\ldots\ldots\ldots (14)$$

and when p and p_0 are expressed in kilogrammes per square centimeter:

$$(p_0^{1.94} - p^{1.94})\ D^5 + .000000000257\ \gamma\ m_0\ L^2\ D - .00000589\ m_0^2\ L = 0. \ldots\ldots\ldots\ldots\ldots (14\frac{1}{2})$$

These equations may be solved by successive approximations.

As the coefficient of the term containing D is very small, a sufficient approximation in practice will be (at least when L is not very large) to simply make

$$D = \sqrt[5]{\frac{.000000552\ m_0^2\ L}{p_0^{1.94} - p^{1.94}}} \text{ or } D = .056\ \sqrt[5]{\frac{m_0^2\ L}{p_0^{1.94} - p^{1.94}}} \ldots (15)$$

when p and p_0 are given in atmospheres, and

$$D = .057\ \sqrt[5]{\frac{m_0^2\ L}{p_0^{1.94} - p^{1.94}}}$$

when p and p_0 are given in kilogrammes per square centimeter.

These values of D will be approached by excess.

CASE OF AN INCLINED PIPE.

If the pipe is inclined it is necessary to consider the increase or diminution of pressure due to gravity. Let α be the angle which the pipe makes with the horizon, α being considered positive if the

pipe inclines downward, and negative if it inclines upward; we have for a state of rest the relation:

$$10334\, d p' = \delta\, d L \sin. \alpha = .606\, p'^{.94} \sin. \alpha\, d L,$$

from which, by integrating between p_0' and p', and between zero and L,

$$p'^{.06} = p_0'^{.06} + .00000352 \sin. \alpha\, L \ldots\ldots\ldots\ldots (16)$$

If p' and p'_0 are expressed in kilogrammes this equation becomes:

$$p'^{.06} = p_0'^{.06} + .00000353 \sin. \alpha\, L \ldots\ldots\ldots\ldots (16\frac{1}{2})$$

The following table gives the values of $p' - p'_0$ for initial pressures varying from 1 to 10 kilogrammes per square centimeter, and for depths varying from 100 to 1,000 meters.

TABLE XII.

Initial Absolute Pressures in Kilogrammes per Square Centimeter.	VERTICAL LENGTH OF PIPE IN METERS.									
	100	200	300	400	500	600	700	800	900	1,000
1	0.006	0.012	0.018	0.024	0.030	0.036	0.042	0.048	0.054	0.060
2	0.011	0.022	0.033	0.045	0.056	0.067	0.079	0.090	0.102	0.113
3	0.016	0.032	0.049	0.066	0.082	0.099	0.116	0.133	0.150	0.166
4	0.021	0.042	0.064	0.087	0.118	0.131	0.153	0.176	0.198	0.219
5	0.026	0.053	0.080	0.108	0.135	0.163	0.190	0.218	0.245	0.273
6	0.031	6.064	0.095	0.128	0.160	0.193	0.225	0.258	0.290	0.323
7	0.036	0.075	0.110	0.148	0.185	0.223	0.260	0.298	0.335	0.373
8	0.041	0.086	0.125	0.168	0.210	0.253	0.295	0 338	0.380	0.423
9	0.046	0.097	0.140	0.188	0.235	0.283	0.330	0.378	0.425	0.473
10	0.051	0.107	0.155	0.208	0.260	0.313	0.365	0.418	0.470	0.523

If the fluid is in motion the differential equation becomes:

$$dp = .0000586 \sin. \alpha p^{.94}\, dL - \frac{.00000285\, m_0 (m_0 - .000872 \gamma D L)}{p^{.94}\, D^5} dL.$$

This equation, if its integration be possible, will give for p an expression so complicated that it will be practically useless.

The increase of pressure, due to gravity, may be computed with sufficient approximation by replacing p'_0 in equation (16) successively by p_0 and by the value of p obtained from equation (13), and taking their average.

Value of D for Which There is No Loss of Pressure.—We may now undertake to find the value of D for which there will be no loss of pressure in an inclined pipe.

It is sufficient for this purpose to make $d\ p = 0$ and $p = p_0$ in the preceding differential equations.

This gives:

$$.0000586 \sin. \alpha\, p_0^{.94} = \frac{.000000285\ m_0\ (m_0 - .000872\ \gamma\ D\ L)}{p_0^{.94}\ D^5}$$

whence $p_0^{1.88} \sin. \alpha\ D^5 + .000004288\ m_0 \gamma\ L\ D - .00486\ m_0^2 = 0$ (17), an equation which will give D by successive approximations.

If we observe that the term containing D is always very small, we see that D will be obtained with an approximation quite sufficient in practice by placing $p_0^{1.88} \sin. \alpha\ D^5 = .00486\ m_0^2$, from which $D = .3446 \sqrt[5]{\frac{m_0^2}{p_0^{1.88} \sin. \alpha}}$.

This value of D may be replaced by a more simple expression by multiplying the two terms of the fraction under the radical by $\overline{.606^2}$, and by replacing $\frac{m_0}{.606\ p_0^{.94}}$ by v_0,

v_0, being initial volume of the steam. Thus we finally obtain:

$$D = .3117 \times \sqrt[5]{\frac{v_0^2}{\sin. \alpha}} \quad \ldots\ldots\ldots\ldots\ldots (19)$$

and, if the pipe be vertical, $D = .3117 \times \sqrt[5]{v_0^2}$ . . . . . (19½) a very simple value which can be adopted in practice.

It can be compared with equation (8) which is applicable to compressed air.

This equation gives by changing to logarithms and expressing D in centimeters,

$$\log. P = \log. 31.17 + .4 \log. v_0;$$

making log. $D = Y$, and $.4 \log. v_0 = x$, the equation becomes $Y - X - \log. 31.17 = 0$.

This represents a straight line inclined at an angle of 45 degrees to the axis of abscissas.

It is represented by the dotted line $A\ B$ upon Chart V., in which the abscissas are supposed to represent volumes, v_0, instead of weights, m_0.

By the aid of this figure, the diameter which must be given to a vertical pipe in order that there shall be no loss of pressure, can be instantly found without calculation.

Suppose, for example, that it is desired to find the diameter of a pipe satisfying this condition and delivering .150 liters of steam per second. By rising along the ordinate corresponding to the abscissa .150 we see that the point of intersection with the line $A\ B$ is at D, and corresponds to 14.5. The diameter sought is therefore 14.5 centimeters.

Calculation gives 14.59.

Example.—Let a pipe 500 meters long be located in a vertical shaft and required to deliver .5 kilogrammes of steam per second, at the initial pressure of 6 atmospheres.

Assuming the condensation to be .8 kilogrammes per square meter and per hour: $\gamma = .8$.

The loss of pressure and the weight of steam available at the lower end of the pipe is required for pipes with diameters of 8, 10, 12, and 14 centimeters.

The following table gives the results of the calculations:

TABLE XIII.

Diameter of pipe	8 c.m.	10 c.m.	12 c.m.	14 c.m.
Weight of steam entering per second m_0	.500 kilo.	.500 kilo.	.500 kilo.	.500 kilo.
Weight of steam issuing per second m	.472 "	.465 "	.458 "	.451 "
Loss of steam $m_0 - m$	.028 "	.035 "	.042 "	.049 "
Percentage of steam lost	5.6	7.	8.4	9.8
Initial pressure p_0	6. atm.	6. atm.	6. atm.	6. atm.
Terminal pressure if the pipe is horizontal p	3.590 "	5.331 "	5.742 "	5.883 "
Loss of pressure $p_0 - p$	2.410 "	.669 "	.258 "	.117 "
Increase of pressure due to gravity $(p' - p'_0)$	.132 "	.151 "	.156 "	.158 "
Pressure at the end of the pipe $(p + p' - p'_0)$	3.722 "	5.482 "	5.898 "	6.041 "

Loss of Energy.—The steam carried in pipes is nearly always employed for driving a motor. It is therefore important to know the loss of energy which results from condensation and from loss of pressure.

We know that when steam expands in a cylinder, while performing work, its pressure and its volume have the relation expressed by the equation $p\ v^{\mu} = \text{const.} \ldots\ldots (20)$

Under the ordinary conditions of working of our engines $\mu = 1.14$.

If we call p and v the pressure and the volume of steam entering the cylinder, p_1 and v_1 the pressure and the volume at the end of the stroke, p_2 the back pressure, we can deduce from equation (20) the indicated power of the steam:

$$W = 10334 \times \frac{p\,v}{.14}\left[1.14 - \left(\frac{v}{v}\right)^{1.4}\right] - 10334\,p_2\,v_1.$$

$\frac{v}{v_1}$ is the reciprocal of the ratio of expansion as $\frac{1}{n}$ is designated.

Substituting $\frac{1}{n}$ for $\frac{v}{v_1}$ the equation for work becomes

$$W = 10334\,p\,v\left(8.143 - \frac{1}{.14\,n^{.14}}\right) - 10334\,p_2\,n\,v,$$

or
$$W = p\,v\left(84142 - \frac{73808}{n^{.14}}\right) - 10334\,p_2\,n\,v \ldots\ldots (21)$$

If p and p_2 are given in kilogrammes per square centimeter, we have
$$W = p\,v\left(81430 - \frac{71422}{n^{.14}}\right) - 10000\,p_2\,n\,v \ldots (21\tfrac{1}{2})$$

v is the volume occupied by steam of the weight m, at the pressure p,

$$v = \frac{m}{.006\,p^{.94}}$$

Substituting this value of v in equation (21) gives

$$W = m\,p^{.06}\left(138845 - \frac{121800}{n^{.14}}\right) - \frac{17053\,n\,p_2\,m}{p^{.94}}$$

m and p are functions of the diameter D of the pipe. By replacing them in the preceding equation by their values in functions of D, and placing equal to 0 the derivative of W, we will have for each value of n the value of D, which will make W the maximum.

Unfortunately, the value found for W, a function of D, is extremely complicated, and the derivative equal to 0 gives an equation from which a definite value of D cannot be deduced.

We are able, nevertheless, by some trials, to find the approximate value of D which gives the least loss of energy.

Returning to the example selected above, and calculating the indicated power which will be supplied to an engine located at a

distance of 500 meters, by a weight of .5 kilogrammes of steam introduced per second at 6 atmospheres pressure through pipes having respectively diameters of 8, 10, 12, and 14 centimeters.

We will make the three following hypotheses:

1. The engine is non-condensing. The ratio of expansion is 1.25; that is to say, that the steam is introduced during only four-fifths of the stroke, which is commonly the case in pumps.

The back pressure $p_2 = 1$.

In this case the indicated power of the engine is

$$W = 12607\ p\ v - 12916\ v.$$

And the loss of work is $12607\ (p_0 v_0 - p\ v) - 12916\ (v_0 - v)$.

2. The engine is still non-condensing, and the back pressure $p_0 = 1^{atm}$. But the ratio of expansion is such that the pressure at the end of the stroke will be equal to p_0; that is to say, to 1 atmosphere:

$$n = \frac{v_2}{v} = \left(\frac{p}{p_2}\right)^{\frac{1}{1.14}} = p_0^{.877}$$

$$\text{In this case } W = 84142\ v\ (p - p^{.877}),$$

and the loss of energy is

$$84142\ [v_0\ (p_0 - p_0^{.877}) - v\ (p - p^{.877})].$$

3. The engine is condensing; the back pressure is equal to one-tenth atmosphere; the ratio of expansion is fixed, and equal to six, a figure which is not often exceeded in practice by engines of average pressure.

The indicated power of the engine is in this case

$$W = 26711\ p\ v - 6200\ v,^*$$

and the loss of work due to the travel of the steam is $26711\ (p_0 v_0 - p\ v) - 6200\ (v_0 - v)$. Making the computations, we obtain the results entered in the table on the following page.

In fact, the work which the steam will be able to perform, whether at the entrance or the end of the pipe, is not so great as the figures in columns 6 and 7 indicate.

It is necessary to consider the effect of the phenomenon of condensation of steam in the cylinder during the admission, in consequence of which phenomenon the volume of sensible steam, that

* If p and p_0 were given in kilogrammes per square centimeter, the values of W obtained by the above formulæ should be divided by 10334.

is to say, the volume corresponding to the admission, is noticeably smaller than that which corresponds to the weight introduced, m.

The quantity of steam condensed internally depends upon the difference of temperatures of admission and of exhaust, upon the regulation, and upon the type of engine. It diminishes if the latter carries compression to the end of the period of exhaust, if the cylin-

TABLE XIV.

Diameter of the Horizontal Pipe 500 Meters Long.	Pressure at the End of the Pipe. p_0.	Back Pressure. p_2.	Ratio of Expansion. n.	Volume of Steam at the End of the Pipe. v.	Work Performed by the Engine. W.	Work Which the Steam Could have Performed at the Entrance to the Pipe. W_0.	Loss of Energy Due to the Travel of the Steam.		Notes.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Meters.	Atmos.	Atmos.		Cu. M.	Kilog.	Kilog.	Kilog.	Per Cent.	
0.08	3.590	1	1.25	0.234	7.577	9.611	2.034	21.16	
0.10	5.331	1	1.25	0.159	8.635	9.611	.976	10.15	(1)
0.12	5.742	1	1.25	0.146	8.693	9.611	.918	9.55	
0.14	5.883	1	1.25	0.141	8.614	9.611	.997	10.36	
0.08	3.590	1	3.069	0.234	10.289	15.304	5.035	32.91	
0.10	5.331	1	4.339	0.159	13.284	15.304	2.020	13.20	(2)
0.12	5.742	1	4.631	0.146	13.664	15.304	1.640	10.72	
0.14	5.883	1	4.731	0.141	13.638	15.304	1.666	10.90	
0.08	3.590	0.1	6	0.234	21.007	23.607	2.600	11.00	
0.10	5.331	0.1	6	0.159	21.670	23.607	1.937	8.20	(3)
0.12	5.742	0.1	6	0.146	21.510	23.607	2.097	8.88	
0.14	5.883	0.1	6	0.141	21.238	23.607	2.369	10.03	

(1) Non-condensing engine with low expansion.
(2) Non-condensing engine with high expansion.
(3) Condensing engine with expansion.

der has a steam jacket, if the expansion takes place in several cylinders, etc.

It may vary from 10 to 25 per cent. of the weight of entering steam.

Consequently, the figures of columns 6 and 7 should be multiplied by a coefficient of reduction varying from .90 to .75, according to the type and performance of the engine.

They are none the less capable of comparison among themselves, and an examination of them leads to some interesting results.

They show that there is, for each type of engine, a value of D which gives a minimum loss of power, and that this loss can be reduced to 8 or 9 per cent. with a pipe 500 meters long, provided the diameter of the pipe be properly chosen, and, above all, that it be well covered.

With the data selected above (to deliver at a distance of 500 meters 500 grammes of steam per second at a pressure of 6 atmospheres), the diameter of pipe most appropriate is 12 centimeters, for a non-condensing engine, and 10 centimeters, for a condensing engine.

It is therefore advantageous, not only in view of the saving in the first cost of the plant, but also on account of the better results from the steam, to not make pipes too large, and to make them of appropriate dimensions for the quantity of steam to be delivered.

Ordinarily, the problem presents itself in a different form from that of the example given above. It consists in determining the proper diameter to make a pipe for conveying steam to an engine situated at a known distance from the boilers, and capable of developing a given indicated power.

Besides the limit of the boilers, that is to say, the initial pressure, p_0 is known.

We proceed by approximations, attributing to p, *a priori*, a value below p_0.

Knowing the type of the motor, the pressure of entrance, and the indicated power to be developed, we can deduce from these data the weight m of steam which the pipe ought to deliver per second at its extremity.

We have m_0 in equation (10):

$$m_0 = m + .000872\,\gamma\,D\,L.$$

Substituting this value for m_0 in equation (14) we have, after making all reductions:

$$(p_0^{1.94} - p^{1.94})\,D^5 - \frac{2097\,\gamma^2\,L^3}{10^{16}}\,D^2$$

$$- \frac{722\,\gamma\,L^2\,m}{10^{12}}D - \frac{552\,m^2\,L}{10^9} = 0 \ldots\ldots\ldots (22)$$

Making

$$D' = \sqrt[5]{\frac{55^2\, m^2\, L}{10^9\,(p_0^{1.94} - p^{1.94})}}$$

we will have a very close approximation to the value of D by substituting D' for D in the second and third terms of equation (22).

If also L does not exceed 1200 meters, we find D with sufficient approximation for practice by simply making

$$D = \sqrt[5]{\frac{55^2\, m^2\, L}{10^9\,(p_0^{1.94} - p^{1.94})}}.$$

or

$$D = .056 \sqrt[5]{\frac{m^2\, L}{p_0^{1.94} - p^{1.94}}} \ldots\ldots\ldots\ldots (23)$$

This equation will give an approximate value of D below the actual.

Taking, for example, the figures from Table XIII., and making $m = .472$, $L = .500$, $p_0 = 6$, $p = 3.59$, $\gamma = .8$, equation (23) gives $D = .0787$ in place of .08, the exact figure. The discrepancy is only 1.3 millimeters; that is to say, is insignificant.

If p_0 and p, instead of being given in atmospheres are expressed in kilogrammes (absolute) per square centimeter, equation (22) becomes:

$$(p_0^{1.94} - p^{1.94})\, D^5 - \frac{2237\, \gamma^2\, L^3}{10^{16}}\, D^2 -$$

$$\frac{770\, \gamma\, L^2\, m}{10^{12}}\, D - \frac{589\, m^2\, L}{10^9} = 0 \ldots\ldots\ldots\ldots (22\tfrac{1}{2})$$

and equation (23) becomes:

$$D = .057 \sqrt[5]{\frac{m^2\, L}{p_0^{1.94} - p^{1.94}}} \ldots\ldots\ldots\ldots (23\tfrac{1}{2})$$

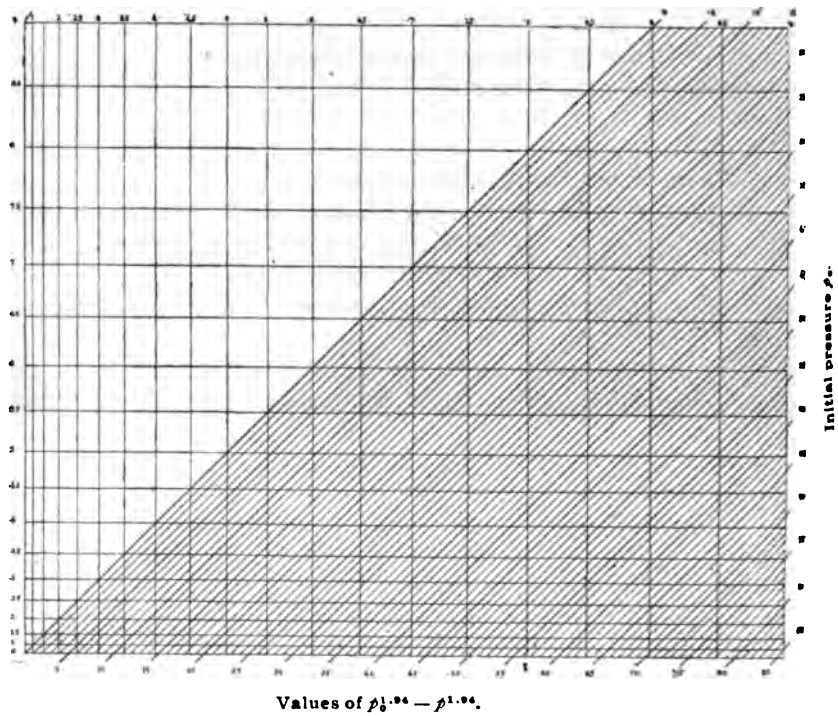
Knowing D, we obtain m_0 by equation (10).

Ascribing then to p, values successively approaching more closely to p_0, we can calculate D and m_0 for each of them. The value of D, for which m_0 is a minimum, should be adopted. It is the most advantageous one, since it is the one which will give the least waste of steam, and, consequently, of combustible.

In order to facilitate the use of equations (15½) and (23½), which give the diameter a function of the initial weight or weight delivered, of the length, and of the initial and final pressures, I have constructed Charts III., IV., V.

CHART III.

Values of the function $p_0^{1.94} - p^{1.94}$ for values of p_0 and p included between 0 and 10.



Equation (23½) gives, using logarithms:

$$\log. D = \log. .057 + \frac{2}{5} \log. m + \frac{1}{5} \log. \frac{L}{p_0^{1.94} - p^{1.94}}$$

Placing

$$\frac{L}{p_0^{1.94} - p^{1.94}} = C.$$

and expressing D in centimeters, $D_1 = 100\ D$; we have:

$$\log. D_1 = \log. 5.7 + \frac{2}{5} \log. m + \frac{1}{5} \log. C.$$

If abscissas are taken proportional to $\frac{2}{5}$ log. m, and ordinates proportional to log. D_1 the preceding equation may be written:

$$Y = X + \text{log. } 5.7 + \frac{1}{5} \text{log. } C.$$

This represents a straight line for each value of C. These straight lines are indicated for various values of C, upon Chart V.

On the other hand,

$$\text{log. } C = \text{log. } L - \text{log. } (p_0^{1.94} - p^{1.94}).$$

By taking for abscissas lengths proportional to log. L, and for ordinates lengths proportional to log. $(p_0^{1.94} - p^{1.94})$ we get the equation log. $C = X - Y$.

This represents a series of inclined right lines, which are shown on Chart IV., and each of which corresponds to a value of C.

Finally, Chart III. gives the values of the function $p_0^{1.94} - p^{1.94}$. It was constructed by giving to abscissas lengths proportional to $p_0^{1.94}$, and to the ordinates lengths proportional to $p^{1.94}$.

Each of the inclined lines corresponds to a certain value of $p_0^{1.94} - p^{1.94}$.

The method of using these charts is given below.

Let us seek, for example, the diameter of a pipe 350 meters long, capable of delivering .758 kilogrammes of steam per second, with an absolute initial pressure of 6 atmospheres, and a loss of pressure of 2.08 kilogrammes.

Chart III. gives: $\overline{6}^{1.94} - \overline{3.92}^{1.94} = 18.$

Chart IV. gives: $\frac{350}{18} = C\ 19.4.$

Chart V. gives: for $m = .758$, $C = 19.4$, $D = 9.2$.

Computing direct by equation (23½) gives $D = .09188$, and, by equation (22½), $D = .0927$. The approximation is as satisfactory as possible.

In order the better to fix this method, I will take the following examples:

Suppose that it is desired to set at the bottom of a shaft 300 meters in depth, an underground pump with compound condensing engine, cutting off at one-sixth, and of which the indicated work of the pistons will be 30,000 kilogrammeters per second; the total length of the steam pipe will be 350 meters; the initial pressure is 6 kilogrammes (absolute) per square centimeter.

CHART IV.

Values of the function $C = \dfrac{L}{p_0^{1.94} - p^{1.94}}$.

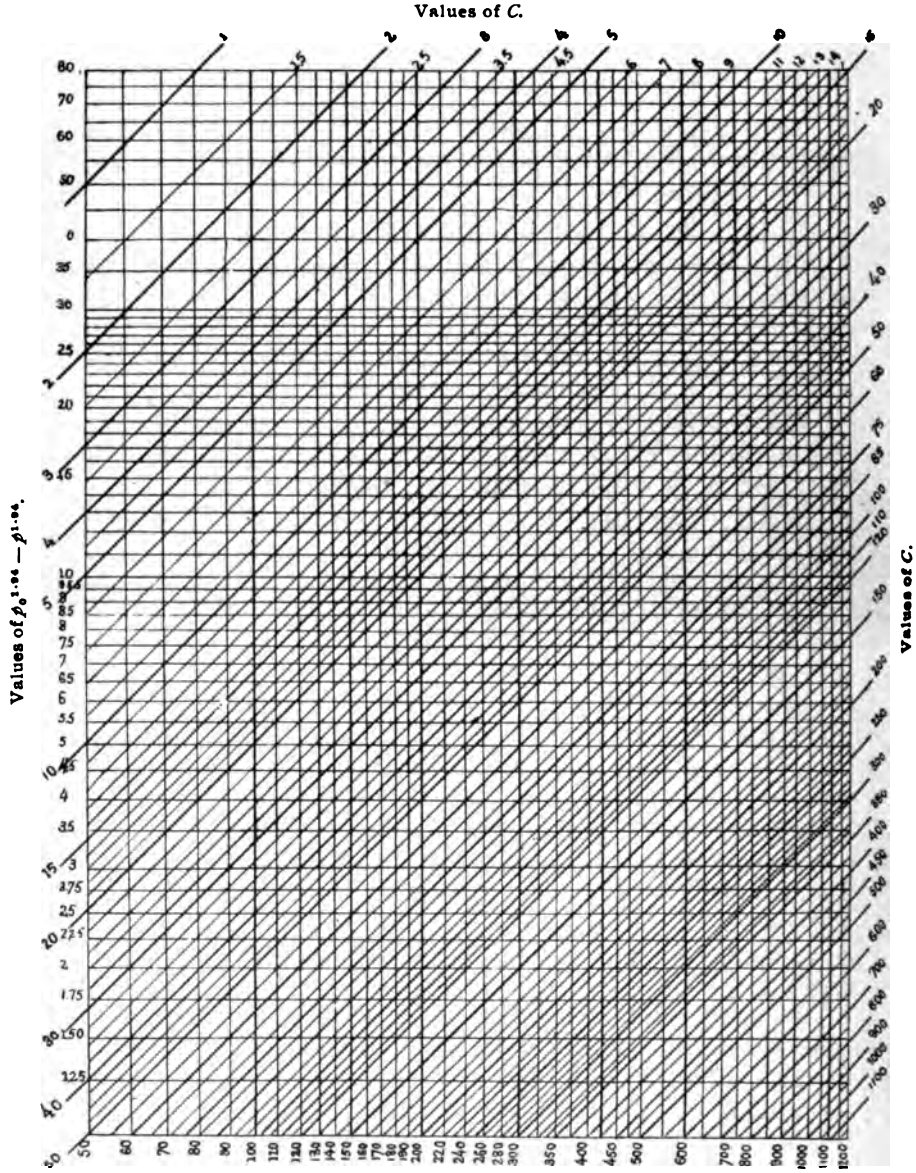
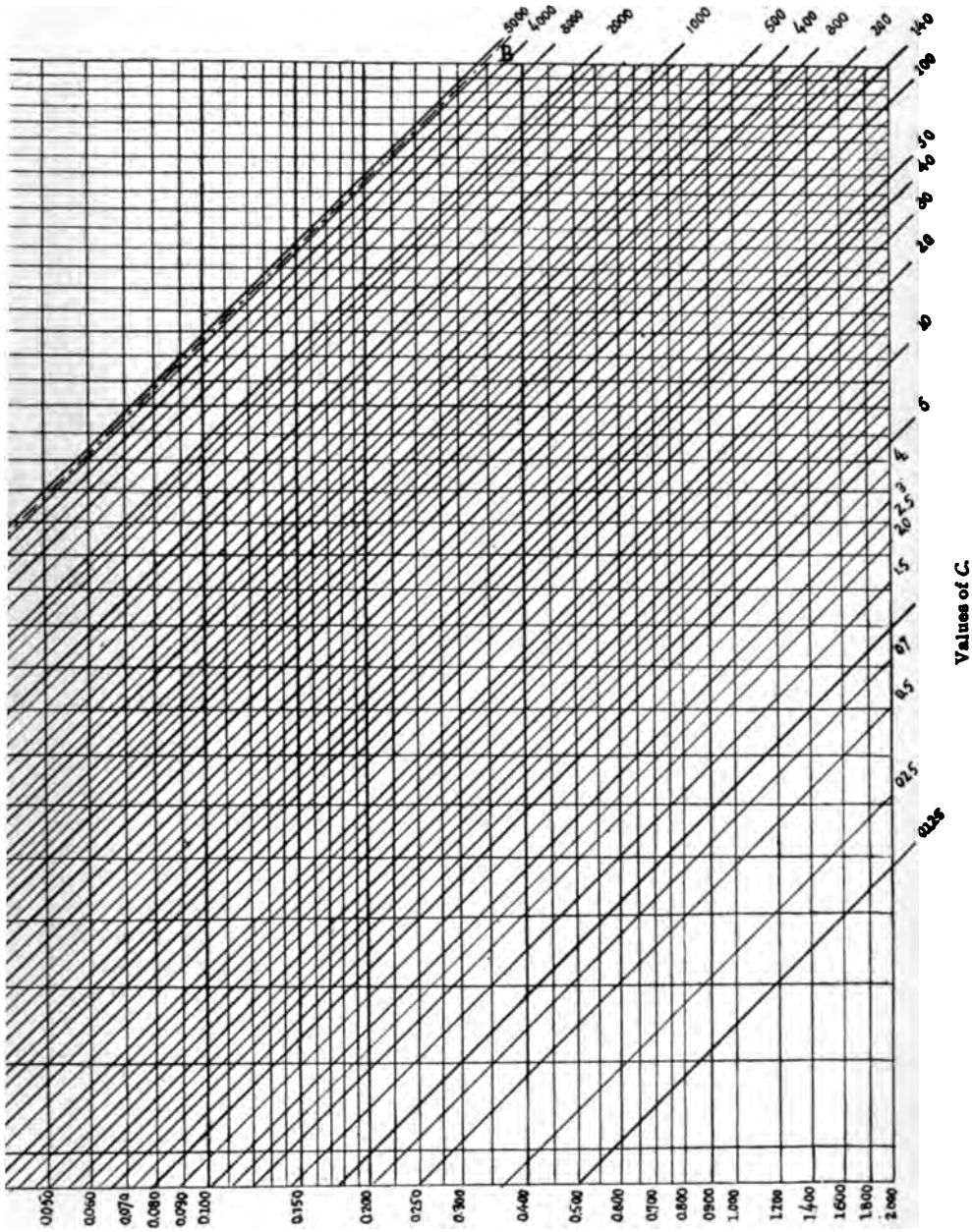


Chart V.

Weights of steam delivered by pipes of different diameters for given values of the function *C*.



Assume that the back pressure will be .1 kilogramme, and that the condensation on the inside of the cylinder during admission will be 12 per cent. of the weight of the entering steam.

Consequently, equation (21½) becomes .

$$30000 = .88\, p\, v \left(81430 - \frac{71422}{6.14} \right) - 6000\, v\, 88,$$

or

$$30000 = (25850\, p - 6000)\, \frac{.88\, m}{\delta},$$

δ being the density of the steam at the pressure which is given in the tables, or finally

$$30000 = \frac{22748\, p - 5280}{\delta}\, m.$$

Taking a former value of p equal to 4 kilogrammes.

The corresponding density $\delta = 2.164$.

The preceding equation gives $m = .758$.

The increase of pressure due to gravity, for an average pressure of 5 kilogrammes and a depth of 300 meters is, according to Table XII., .08 kilogrammes.

The loss of pressure due to friction will then be 2.08 kilogrammes, and the final pressure $p = 3.92$ kilogrammes.

We know that $L = 350$, and that $p_0 = 6$.

We can find D either by equation (23½), which gives $D = .0919$; by equation (22½), from which we deduce $D = 0.927$; or finally by the charts, which give $D = .092$.

Equation (10), if γ be supposed equal to .8, gives $m_0 = .781$.

Making similar computations for

$p =$	4.75	5.5	5.75

we find

m	= .742 kilogramme,	.73 kilogramme,	.726 kilogramme.
D	= .098 meter,	.114 meter,	.128 meter.
m_0	= .766 kilogramme,	.758 kilogramme,	.758 kilogramme.

For a value of D between .114 and .128, m_0 is a minimum, and, as it is advantageous to use the smaller diameter, we make $D = 11.4$ centimeters.

RÉSUMÉ.

The preceding equations and tables admit of the solution of most of the problems which involve the transfer of power to a distance by means of steam or compressed air through *straight* pipes.

I think it will be useful to recapitulate here the various equations which can be currently employed in practice.

COMPRESSED AIR.

The pressure p, at the end of a horizontal pipe, of length L and diameter D, into which a volume Q_0 of air enters, at the pressure p_0 and at the absolute temperature T_0, is given by the expression,

$$p^2 = p_0^2 \left(1 - .0001012 \frac{Q_0^2 T L}{T_0^2 D^5}\right) \ldots\ldots\ldots\ldots (4)$$

The diameter of a pipe in function of initial and final pressures, of the initial volume and of the length, is

$$D = .1589 \sqrt[5]{\frac{Q_0^2 T L}{T_0^2 \left(1 - \frac{p^2}{p_0^2}\right)}} \ldots\ldots\ldots\ldots\ldots (5)$$

and if we make $T_0 = 288$, and $T = 293$, which is the usual case:

$$D = .05137 \sqrt[5]{\frac{Q_0^2 L}{1 - \frac{p^2}{p_0^2}}} \ldots\ldots\ldots\ldots\ldots (5\frac{1}{2})$$

In a straight pipe inclined to the horizon at an angle α, the pressure at the end, for a state of rest, is:

$$p = p_0 \, e^{\frac{.0341 \, L \sin. \alpha}{T}}$$

and for a state of motion:

$$p^2 = \frac{.001475 \, Q_0^2 \, p_0^2 \, T^2}{\sin. \alpha \, D^5 \, T_0^2} \left[1 + \left(\frac{\sin. \alpha \, D^5 \, T_0^2}{.001475 \, Q_0^2 \, T^2} - 1\right) e^{\frac{.9682 \, L \sin. \alpha}{T}}\right]$$

In these equations α is taken positive if the pipe is inclined downwards, negative if inclined upwards.

Finally, in a pipe inclined downwards, there is no loss of pressure when the diameter satisfies the equation

$$D = .2718 \sqrt[5]{\frac{Q_0^2 T^2}{\sin. \alpha \, T_0^2}} \ldots\ldots\ldots\ldots\ldots (8)$$

If the pipe is vertical, and if $T = T_0$, which is the usual case in air shafts:

$$D = .2718 \sqrt[5]{Q_0^2} \ldots\ldots\ldots\ldots\ldots (8\frac{1}{2})$$

In all the above equations, p and p_0 are expressed in atmospheres or in kilogrammes per square centimeter, L and D, in meters, and Q_0, in cubic meters.

STEAM.

Calling m_0 the weight of dry steam sent per second through the entrance of a pipe, and m the weight which reaches the other end, expressed in kilogrammes, p_0 and p the initial and final pressures, L and D the length and inside diameter of the pipe in meters, γ the weight of steam condensed per hour and per square meter of interior surface of the pipe, we obtain the following relations:

$$m = m_0 - .000872\,\gamma\,D\,L \quad \ldots\ldots\ldots\ldots (10)$$

If p and p_0 are expressed in atmospheres

$$p^{1.94} = p_0^{1.94} - \frac{.000000552\,L}{D^5}\,m_0\,(m_0 - .000436\,\gamma\,D\,L) \ldots (13)$$

and if p and p_0 are expressed in kilogrammes per square centimeter

$$p^{1.94} = p_0^{1.94} - \frac{.000000589\,L}{D^5}\,m_0\,(m_0 - .000436\,\gamma\,D\,L). (13\tfrac{1}{2})$$

These equations give any one of the quantities m, m_0, p, p_0, L and D, when the others are known.

If the length of the pipe does not exceed 1200 meters, the diameter corresponding with the pressures p_0 and p, is obtained with sufficient accuracy for practice, from the equations:

$$D = .056 \sqrt[5]{\frac{m_0^2\,L}{p_0^{1.94} - p^{1.94}}} \quad \ldots\ldots\ldots\ldots (15)$$

if p and p_0 are expressed in atmospheres, and

$$D = .057 \sqrt[5]{\frac{m_0^2\,L}{p_0^{1.94} - p^{1.94}}} \quad \ldots\ldots\ldots\ldots (15\tfrac{1}{2})$$

if p and p_0 are expressed in kilogrammes per square centimeter.

The value of D thus found will be approached by excess.

When the pipe is not very long, and when it is well covered m differs little from m_0. If then m and not m_0 be given, we find D with sufficient accuracy by making

$$D = .056 \sqrt[5]{\frac{m^2\,L}{p_0^{1.94} - p^{1.94}}} \quad \ldots\ldots\ldots\ldots (23)$$

This gives a value of D approached by deficiency.

If it is desired to obtain a closer approximation, m_0 may be calculated from equation (10), by means of this first value of D. Equation (15) will give finally a second value of D approached by excess. The mean of the two values of D thus found can then be taken.

If the pipe is inclined the change of pressure in the static condition is given by the equation:

$$p^{.06} = p_0^{.06} + .00000352 \text{ sin. } \alpha L \ldots\ldots\ldots\ldots (16)$$

in which p and p_0 are expressed in atmospheres, or

$$p^{.06} = p_0^{.06} + .00000353 \text{ sin. } \alpha L \ldots\ldots\ldots (16\frac{1}{2})$$

if p and p_0 are given in kilogrammes per square centimeter.

There will be no loss of pressure in a pipe inclined downward when D satisfies the equation:

$$D = .3117 \sqrt[5]{\frac{v^2}{\text{sin. } \alpha}} \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

v_0 being the initial volume of steam entering the pipe.

If the pipe is vertical this equation becomes

$$D = .3117 \sqrt[5]{v_0^2} \ldots\ldots\ldots\ldots\ldots\ldots (19\frac{1}{2})$$

THE ELECTRICAL ENGINEER AND HIS RELATION TO MECHANICAL ENGINEERING.

ADDRESS BY C. J. FIELD, PRESIDENT OF THE ALUMNI ASSOCIATION, DELIVERED AT THE SEVENTEENTH ANNUAL MEETING.

To the Fellow Members of the Alumni Association of Stevens Institute of Technology: Following the established custom in this matter, it becomes my duty, as well as my pleasure, to address you to-night on some subject connected with our profession. I have, therefore, chosen this one in covering the question of our relation as mechanical engineers to the profession of electrical engineering, which at the present time is attracting so much attention, and making such remarkable strides and developments in the engineering profession in general.

The question arises with the young student who desires to take up the study of electrical engineering, as to which course is

the best suited for his requirements. Our Alma Mater has tried to answer this by taking the stand that her course of mechanical engineering qualified and equipped the student to enter the ranks of electrical engineers. This stand had been taken on the assumption that three-fourths of electrical engineering is mechanical engineering.

Without attempting to go too exhaustively into this subject, I will try to point out briefly what seems to me, from my own experience, to be an endorsement of these views in every respect. I feel that we may safely assume that the young electrical engineer, entering the profession to-day in almost any department or branch of it which is at all progressive, will find that fully three-fifths of his work requires a full knowledge and training in mechanical engineering in its broadest sense, as exemplified by the course at the Institute, and that not more than two-fifths of it, at the most, taking a general average, will be found to be electrical engineering, pure and simple.

Electrical science to-day is in a more active stage of development and progress than the older and more established branches of engineering—civil, mining, marine, and mechanical. The electrical engineer, therefore, requires, in order to fully enter the lists with his co-workers in this line, and make that progress which all young engineers are desirous of doing, to be qualified to take part in the designing and construction of apparatus and works which are going on now the world over in connection with his profession. This we consider to be the real basis for what has proved to be the requirements in this line. There is hardly any department of the profession of electrical engineering in which questions are not continually arising in a day's work, which can only be answered by a knowledge of mechanical engineering; that is, in the designing of all the apparatus which is now being manufactured in the different branches and departments of this profession, in their working, and in the building and equipment of the works, plants, roads, and machinery in which this apparatus is entering so largely and play-

ing such an important part. The young engineer who is not prepared and ready to take it up in this sense will find his field of progress and development restricted to a much narrower channel, and to be much slower in every respect; and he will be compelled, as we have seen many of them do, to qualify himself more fully as a mechanical engineer in order to keep up with others who have started along with them.

We will take, for instance, a few examples which come more prominently before us, of what the electrical engineer may be called upon to do in this line on some of the few things which he is liable to encounter. For instance, in the designing and building of electric power generators and motors, experience has shown, in every apparatus of this kind which has been built by the different companies, that the calculation and determination of the electrical quantities and parts of the apparatus have, in the few short years in which they have been in a stage of development, become so perfected that they show to-day in this part a higher efficiency than any other generator or transformer of power.

It is, however, in the designing of the apparatus that the greatest difficulty has been experienced, to secure their proper working from a mechanical standpoint, and we have had, in this line, a number of examples of the brilliant electrical design of apparatus, which has failed utterly in its working, caused by a lack of proper knowledge and experience in the designing of its mechanical parts.

We may take as another example the building of an electric railway plant. Let us look for a moment into the different qualifications which an electrical engineer must have, and the difficulties he has to encounter, to properly qualify himself and meet the requirements and expectations which are placed on him in many works of this kind. They cover not only a full knowledge and experience with all classes of generators and motors, but also of cars, their framing, equipment, trucks, wheels, rails, steam plant of the best and most efficient type to meet the varied requirements

and conditions found in different cases, capacity to design power stations and car houses complete in every respect, with a knowledge of foundations required for the machinery and its operation, the building of road bed complete, and the paving of the streets in connection with the same, installation of underground conduits and feeder wires in connection therewith, and erection of overhead structures. Wherein can anyone more fully and more adequately obtain the groundwork and basis from which to develop himself to meet these varied requirements and qualifications, than by a thorough groundwork in mechanical, as well as electrical, engineering, as given in such a course as we have at our Alma Mater?

It is often said, "Show us the proof of all this reason and argument." We have only to look around through the electrical engineering field, among those young men who are prominent in positions of trust in the different manufacturing companies, in the different local companies, electric lighting, railway, and in every branch of business in which the electrical engineer is connected, and see who are the trusted and prominent ones in charge of such work, and we will find almost universally they are the young men who have had the training and qualifications in mechanical as well as electrical engineering, who have been placed in these positions of trust.

COMMENCEMENT WEEK.

THE Baccalaureate Sermon was delivered by Rev. William R. Jenvey in St. Paul's Protestant Episcopal Church, Hudson Street, Hoboken, on Sunday, June 18.

At the invitation of Mrs. Edwin A. Stevens, the Class Day exercises, on the afternoon of the 19th, were held at Castle Point, where, with music and humorous addresses, the graduates entertained their numerous friends. At the close of the Class Day exercises, Mrs. Stevens extended, through President Morton, a gracious invitation to all present to remain and participate in the reception to be given to the graduating class at the Castle.

At 8 o'clock, the Class of '95, accompanied by hundreds of students and sympathizers, formed in procession, and, after pursuing a line of march which ran through the principal streets of the upper part of the city, returned to the Campus, where the trial and cremation of Calculus took place, with ceremonies appropriate to the occasion.

The Class of '90 held a triennial reunion at Clark's, Twenty-third Street, New York, on the evening of the 20th.

Among the social events of the week, the Senior promenade on Tuesday evening, at the Quartette Club Hall in Hoboken, was one of the most enjoyable.

As has been their pleasing custom, President and Mrs. Morton gave their annual reception to the Faculty, Alumni, and undergraduates on Wednesday afternoon.

The Alumni Association held its annual meeting in the Hall of Stevens School on Wednesday evening.

The Commencement Exercises proper were held on Thursday evening in the Hoboken Theater, where the relatives and friends of the members of the graduating class assembled to witness the closing exercises of their college careers.

On the right half of the stage were seated the Faculty and Trustees, while the left half was occupied by the Class of '93.

The exercises were opened with prayer by Rev. Edward Wall. President Morton followed with introductory remarks, and Mr. Hermann F. Cuntz then delivered the following Salutatory address.

Mr. President, Trustees, Faculty, Friends: The class of '93 extends its most hearty greeting. It welcomes you here, one and all.

Nearly four years ago we began our education in engineering; then it was that many of you, my hearers, may have anxiously awaited the report that the entrance examinations had been successfully passed by a son, a brother, or a friend. In all his college life, as the years went by, your interest in him was confirmed. In his studies, athletics, and all college enterprises, you applauded his successes; and, as we now set out, those bright moments become the landmarks which we see most prominently, when looking back along the path of life.

And when, as at the present, we reach a station where we part with our guides in the road of knowledge, it is pleasing and encouraging to be greeted on our journey. While each of us feels the eager gaze of kinsman or dear acquaintance centered upon him, each fully realizes that he is one in this great world whose failings may cause sorrow, but whose successes will give great joy to many a heart; and so are we strengthened, we feel ambition and energy take full possession of us, and thus find it an easy task to step to positions of responsibility, of trial and of enterprise—to mingle with a great and noble army of workers.

We regret the absence this evening of many who might have been before you. But our class history is in many respects not different from others. A bright sun shone in our daily lives as each term began, but it dimmed, it was darkened as the three months drew to a close. Among those who started with us, but are now missing, one has been called to rest, some have struck out on the tide of life in other directions, others are now struggling to gain a

firm footing on those shores of success, which we, who graduate to-night, see before us, let us hope, not too far off.

"Years ago war was a business," Erastus Wiman has said; "to-day, however, business is war." This means it is the able, the energetic, the courageous and the bold young man, who will make for himself a name in the world. Herbert Spencer says, that "on the application of rational mechanics depends the success of all modern manufacture." And, as a hint, Mr. Wiman again tells us, "The way to succed is to supply a want."

Consider these ideas, and you have the explanation for our choice of a profession—a profession whose followers are the practical leaders in the modern world. Where the financier strives to lead, the engineer directs; he must be consulted. Where does the rich man invest his capital? Where is most all capital invested, but in engineering projects? Of what value is real estate unimproved by engineering or implements built by the engineer?

If I may be allowed to use the reference, just made by our worthy President, to those small and unseaworthy caravals, true copies of which have recently entered our great harbor, do you think that any in their crews would have ventured to undertake the voyage which Columbus did, unless they had had a great leader—one who had already solved the great problem with his brains?

Thus, it is the engineering minds that guide the world, not alone the engineering hands.

However careful may be the *engine-driver*, he can reduce only in a limited degree certain running expenses. While the *engineer* is constantly lowering those expenses. His aim is high efficiency. What is he but a power economist? It is he who is constantly prescribing and devising and designing plans for the continuous small savings in the production of each power unit, which amounts to millions in the aggregate.

I know you acknowledge our profession a grand one. One which, when ably pursued, ensures success; successfully pursued means happiness.

But, in the future, some days, or some months, may find our minds absorbed in an enterprise both perplexing and worrying; moments come when our prospects seem very gloomy; then we need encouragement. Then it is, that we will look back upon those happy, joyous days spent at our Alma Mater. Then it is, that the remembrance of the many kind and interested faces before us at this graduation will ever act as a stimulus to our energy, will constantly draw us on in cheerfulness to whatever our emboldened hearts and spirits may dictate, and to whatever pluck, determination, ambition, and perseverance can obtain.

Blessed with these happy thoughts—armed with the knowledge imparted to us by these, our worthy professors, we, of the class of '93, part this night; we step to the battlefield of life, to manhood's duty.

HERMANN F. CUNTZ.

Mr. Alexander C. Humphreys, M. E., was followed with the closest attention as he delivered the address to the graduating class.

Members of the Class of '93: In accepting President Morton's invitation to address this year's graduating class, I fully appreciated that the duty was an important one.

Had I felt after considering the subject that the occasion demanded an exhibition of oratory, I should not have accepted the responsibility. But I concluded that what would be at least appropriate would be some words as to the paths ahead as yet by you untrodden, some words of encouragement as to the prizes to be won, some words of warning and direction as to the dangers, obstacles, and temptations to be met and overcome, and the right path to be followed if you would truly succeed.

Then, for the moment, I am simply before you in the capacity of guide, and the language chosen need only be direct and free from ambiguity. A guide of more years and greater experience might easily have been selected, but as that has not been done, we

must co-operate to obtain from the arrangement as made the best possible results.

At least I take up the pleasant task with a heart full of sympathy for you, one and all, in the hopes, ambitions, honest determinations to succeed, and fears, perhaps, which are to-night present with you. As I perform this duty, I keep constantly before me the hard experiences through which I have learned, and am learning, my lessons; and I must carefully and honestly study those experiences, and, as well as I can, give you the result. To be of any effect my words must find a response in your hearts; this response should be the more ready on account of the experiences you have already had.

Your whole training in Stevens has been to enable you as engineers to avail yourselves of the experience of others who have preceded you. If this applies to one part of your life's work, let it apply to all.

Looking back, I can see how much easier paths I might have chosen, and how many obstacles and troubles I might have avoided; how much better and easier my work might have been done.

I know that some think that in these matters personal experience is the only effective teacher. While very effective, it is very, very severe. If I can save you from the operation of some of its painful methods, I shall feel thankful indeed.

If what I have to say clashes wholly or in part with your preconceptions, at least let my words be so far heeded as to cause you to reconsider the questions involved, and again give them careful, candid consideration.

This is a bright night in your lives, and it is well you should fully appreciate its brightness and its promise. It is momentous chiefly because you have come to the end of a course of training distinctly preparatory, and you are now about to be declared as sufficiently equipped to commence the practice of your profession.

This, then, means not the completion of a wearisome round of labor and the entering into a season of rest, but the beginning of the larger work for which you have been trained. Does this fact as again brought to mind dismay you? No; because, as brave, hopeful men, it is the work and the conquering which you look forward to so eagerly.

Then, should I apologize for making this the occasion for some serious words, instead of simply passing the matter off with words of flattery and congratulation?

You are to be congratulated, most warmly so. You have passed through "Stevens," and can go out to the world with its certification as to your efficiency as workers in your chosen calling. You have spent four years of constant study in what I believe to be the best, or equal to the best, institute of its kind in the world. You have had the advantages of an advanced, well-balanced course of instruction, under a thoroughly competent, fair-minded, earnest Faculty, presided over by a man peculiarly endowed and equipped for his work.

Let me then warmly congratulate you upon your work so far well done, and let me heartily welcome you into the ranks of the world's workers, where I know you are all so eager to take your places.

But, while extending this welcome, I warn you that in our ranks your self-esteem will receive many rude shocks. If your self-esteem is abnormally developed, and partly so, perhaps, because you can after your names write M. E., S. I. T., then it were well for you that the shocks should come promptly and with severity. Blessed is the man who quickly gets his conceit so reduced to the normal.

If you are inclined to stop to think of the great things you can do, and of the great knowledge you have acquired, also stop long enough to think how comparatively small a thing is the knowledge of the greatest of our leaders. If you wish, as you go along, to apply a test as to your growth in wisdom, see if you are also becoming more modest in appreciation of your acquirements.

In your four years of work just completed you have no doubt been obliged to meet and overcome many difficulties. So, by your success, you have not only reached the goal you have been striving for, but you should have gained in mental and moral strength, and should be now better able to cope with the tasks that are ahead of you. In future, when you come to the place where the task you have undertaken seems more than your strength is sufficient for, remember the trials of the past four years, and remember the successful termination. Remember that even average ability combined with honest work and perseverance will accomplish great results. Especially remember that your bridges do not have to be crossed until you come to them. Many men wear themselves out worrying about the trials which they are never called upon to meet. And even if you have in time to meet them all, you have to meet them only in succession. Think of the principle of the lever. If the troubles were all concentrated and had to be overcome with one effort, you could not succeed, but they are spread over time, and so a moderate effort continuously applied brings you over the troubles, which at times to your excited imagination have loomed up ahead mountains high.

But, on the other hand, do not imagine that in competition with those who cannot write "M. E." after their names, you will have a "walk-over." No greater mistake can you make. You now simply stand equipped to take up to the best advantage the study and practice of your profession. For now the study and practice must go hand in hand. No longer can your work simply be preparatory.

Even if any of you intend to take up post graduate work, I remind you that there is a decided disadvantage in too long studying without testing by application the things learned.

As engineers you should understand and put into effect that harmony of theory and practice of which "Stevens" tries by its course to demonstrate the value. In this connection I urge you all to read, carefully read, Rankine's "Dissertation on the Harmony of

Theory and Practice," which appears as an introduction to his Applied Mechanics.

I confess, I did not read this through until after I had left "Stevens." I have read it a number of times since, and always with profit.

As an employer of engineers, if I were forced to make choice, I would, as a rule, select for work to be done, the hard-headed, practical man, rather than the technical man who does not appreciate the necessity for the harmony of theory and practice. But do not misunderstand me. I am now talking for the benefit of a class of men which, I hope, is not represented in the class before me. I have, however, though not often, come across such amongst "Stevens" graduates.

The engineers of to-day must, as Rankine says, possess "That scientifically practical skill which produces the greatest effect with the least possible expenditure of material and work"; he must be a "practical scientist."

Bear in mind also that talent and education are not sufficient to satisfy the intelligent employer. The employee must first satisfy him as to his loyalty and his common sense. If the employee is disloyal, the more able he is, the worse it is for the employer.

But, while I thus advise proper modesty as to your requirements, I also advise you to have the courage of your convictions.

Do not be in haste to express your opinions but, when your opinions are fully formed, go bravely ahead, though with minds open to further light. Once convinced that you have been wrong, be men enough to face the music and acknowledge your errors. Make up your minds in advance that you cannot always be right, but that you will always follow the right as soon as it is seen.

Do not fear to acknowledge that the problem presented is beyond your present powers, but couple with the acknowledgment the resolve to acquire the lacking knowledge and experience.

e employee who acknowledges the facts, but, at the same time,

convinces the employer that he is willing and able to take hold of the problem with honesty, intelligence, and perseverance, will, in most cases, be given full opportunity to demonstrate his capacity.

Do not be weakly vacillating because you cannot choose the most efficient course to pursue between two or three that offer. If, after honest study, you cannot make up your mind, go ahead on either course, and go ahead with all the more vim because you are in doubt. Thus, will the energy you put into your effort compensate for the partial mistake in choice, if such has been made. In business it is well understood that a poor venture well handled will generally give a better return than a good venture poorly handled.

Whatever you do, do with all your mind and force. Be thorough. A smaller amount of work well done will give you and your employer far more satisfaction than a larger amount imperfectly done. Slight nothing; do only so much as you can do thoroughly. I beg of you here to be honest to yourselves; and, if not already learned, learn this lesson at once. Remember, the responsibility must rest with you who assume it—not with the one who tries to place upon you the too great burden.

Do not fear criticism if you have honestly done your best. Learn from it if you can. It is much easier to criticise than to perform. Remember this also when you are inclined to be the critic.

Do not worry yourselves or others by making excuses for the mistakes made. Learn from the experience, and let it rest at that. I know of no more tiresome employee than the man who is always ready to tell why he failed to come up to expectations. Before long the tendency is to select a man who will not, by uncandid and tiresome explanations, add to the troubles he makes.

Be neither too timid nor rashly bold. Here, as elsewhere, extremes meet in an outcome which is humiliating and perhaps disastrous.

Do not neglect to study, and especially to perfect yourselves in all pertaining to your chosen calling. As engineers you can, in this age of keen competition, do best in business by being specialists. Then study and work hard to thus excel. Hard work, remember, will not injure a man of fair physique, if this work is not intemperately performed. This means that bodies and minds must have rational recreation. They must be maintained in a state of high efficiency. If you can keep free from worry, you can, if you will, safely perform a large amount of work.

In your business, while perfecting yourselves as specialists as far as the technical points are concerned, remember that there are certain things which should be neglected by none. For instance, you can well afford to study the principles at least of double-entry bookkeeping. An engineer, educated in mathematics, should find it comparatively easy to understand these principles. As it may not pay you to acquire great facility in the handling of tools, so it may not pay you to equip yourselves as expert bookkeepers. But you can understand the principles without this facility of execution. Gain at least such knowledge that you can decide as to a proper classification of the accounts involved in your business, and be able, at least, to understand a ledger trial balance, a profit and loss statement, and a statement of assets and liabilities. How else can you analyze for yourselves the commercial results obtained ?

You will need a certain amount of this kind of knowledge to enable you to properly care for the savings which it is your duty to begin at once, if possible, to accumulate.

Do not try to satisfy yourselves on this point by saying that you are engineers, not business men. As a rule the engineer must also be a business man, at least to the extent of properly appreciating the value of money.

If circumstances permit you to choose your specialty, try to follow the line of work which appeals to your taste. That is, try to develop along the line of least resistance.

Follow the line in which the quality of your work performed is the best, whether it be strictly technical, strictly executive, or a combination of both.

Just as far as your temperament will permit, try to be cheerful and bright in the performance of your work. Work done cheerfully wears upon the worker far less than the same work done under protest. It is only fair to remember that cheerfulness in the employee is agreeable to the employer.

I know it is hard to always persevere in your work unless by the exercise of dogged resolve. In spite of the extra wear, better a hundred times to so persevere than to give up.

Recognize fully the value of tact. The man who combines tact with real ability can be intrusted with matters beyond the reach of a man qualified in all else, but lacking in this respect.

But, do not confound tact with diplomacy or *finesse*. When I advise you to exercise tact in meeting your fellow men, necessarily I advise you to be honest, direct, and courteous. It is seldom that the diplomatist is truly any of these three.

Do not think that because another man's work gains him a certain reward or acknowledgment, that your work is therefore entitled to certain returns. Each tub must stand on its own bottom. Jealousy engendered by this kind of senseless comparison has occasioned many heart-burnings. In this connection again remember that worry will wear you out more than work.

In measuring success look below the surface. See if the success you are perhaps inclined to envy has led to anything like real content.

Do not go to extremes. While competition in business may force you to be a specialist, aim also to be broad-minded, cultured gentlemen. That is, cultivate where you are strong, as far as your specialty is concerned, but cultivate where you are weak, where your character is concerned.

Remember that the greater your natural ability, physical strength, and capacity for work, and the greater the educational

advantages you have enjoyed, the greater is the responsibility resting upon you for the performance of a full amount of high grade, thorough work.

Study the physical and mental powers with which you have been entrusted, and see how best you can use them in your life's work; and do not take a selfish view of that work and its scope. Look abroad and see what claims the world has upon you. I beg you to remember that these claims will assert themselves, and the calls should not go unheeded. Do not refuse to take part in public and social affairs because it is too much trouble, or because "there is nothing in it for you." In this connection, do not forget, as opportunity offers, to do your whole duty by your Alma Mater.

And, now, as to money. What shall I say? Some will tell you that you should make its acquisition your chief study and care. Others will tell you to despise it; to regard it only as the root of all evil. Then I will again advise you to avoid extremes.

You all know without any word from me, that the man who becomes absorbed in money-getting also becomes hard and selfish, and you have no wish to reach that condition. But you do, perhaps, need to be warned that many by too fervently wishing for money gradually develop into the narrow-minded money-getter.

The man who acquires great wealth certainly must be weighted down by the responsibility of its care, and especially so in his declining years, when he should be laying aside his burdens. Great wealth must be a tremendous test of character.

But, on the other hand, it is a man's duty, to try during his years of greatest efficiency to lay by for the years to follow, when his earning capacity may be reduced, or perhaps entirely cut off. Also, he must think of the days ahead, when his financial responsibilities will probably be increased. Therefore, it is a man's duty not to be improvident. It is his right and his duty to aim to acquire a competency.

Now, how shall this effort be made?

One simple rule, if followed from early enough in life, will almost always lead to this result, and will also relieve him during his working years of one of the greatest, if not the greatest, source of worry—viz., financial embarrassment. The rule is, spend less than you earn. Save part of your income, if only $1 per year. Even that small sum saved will at least keep you from running into debt. I know it will seem a very slow way to acquire even a competency, but the great money-getters tell us that compound interest is, in the long run, the surest and quickest way to accumulate; and we must not forget that money saved is very different from money quickly acquired. The first cultivates in us self-control and simple tastes; the latter cultivates recklessness and extravagant tastes. Thus, while in the latter case the money is coming in rapidly, it flows out perhaps even more rapidly. On the other hand, the money saved stands a far better chance of being retained. As a rule, the man who suddenly becomes rich, as suddenly becomes poor; and certainly his last condition is worse than his first.

But let us before closing turn to things less material.

Do not be ashamed to have before you a lofty ideal; strive continuously to live up to it. Do not let the failures which must occur lead you to throw off your allegiance to your ideal.

You will often come to a place where you will find it difficult to decide upon your course. Let your test question first and last be: "Which is the right?" That "still small voice" will, if encouraged, answer the question. You all have found that there is no real gain or satisfaction to be obtained in going contrary to the guiding of that voice. And this you have found irrespective of your individual religious views.

But I feel that such a talk as this would be essentially lacking if I did not more directly refer to that power which you can, if you will, call to your aid. According to my belief, the voice of conscience, whose presence all here will acknowledge, is one manifestation of that power.

You have, at the best, many trials and tests ahead of you, and perhaps these trials may come to you in forms which now appeal to you as good and pleasant. In our day it has become in certain circles almost a fad to scout at the beliefs of our fathers. This is in part due to the truth having been often mixed with much human error, the doubters not recognizing or forgetting that such must be with us the course of development of all truth.

But do not think, as so many young men to-day do—or pretend to do—that, because you have a partial education in science, you can afford to scout at these old beliefs. Stop, and think what a very insignificant thing, after all, is the knowledge of those who tower intellectually above you and me. Do we find these very wise men able, through their knowledge, to avoid the pitfalls, dangers, and temptations of life? On the contrary, do we not often find them to be the weakest of the weak? But do not we all recognize that there is a strength outside, independent of, above this mere earthly knowledge?

My personal belief is that this power we can all lay hold of, and that there is nothing which will take its place. By laying hold of its fatherly, correcting, sustaining hand, many of our difficulties will vanish, and our strength will be made sufficient for those other trials, which, for the development of character, it is necessary we should meet and conquer.

Gentlemen, I hope that the length of my remarks has not by wearying you destroyed any value that they might have had.

In conclusion, let me wish you God-speed, and the greatest measure of true success in the way now opening so brightly before you.

The degree of Mechanical Engineer was conferred by President Dod, of the Board of Trustees, upon each of the graduates, whose names, and the subjects of whose theses, are given herewith:

HARRY H. ADAMS. WILFRID K. HUNTER.
Test of Bergen and Jersey City Electric Railroad.

WILLIAM B. AXFORD. FRANK J. WEEKS.
Test of Refrigerating Plant of the Hodges and Havenstrite System.

CHARLES T. BAYLESS. ARTHUR E. MERKEL.
Cremation of Garbage in America.

ALVIN V. BOODY. HERMANN F. CUNTZ.
Test of Electric Light Plant, Stokes Building, New York City.

BANCROFT G. BRAINE. JAMES V. MACDONALD. CHARLES H. MERRITT.
Test of Otto Gas Engines Operating an Electric Light Plant with Producer Gas, Danbury, Conn.

BENNET B. BRISTOL. RICHARD E. CHANDLER.
Design of High-Speed Vertical Steam Engine.

AUGUSTUS B. BROOKFIELD. ALBERT E. BRUEN.
Test ot Electric Light Plant, Madison, N. J.

HERBERT B. COOK. ALFRED B. LORD.
Determination of the Water Consumption of a Ball and Wood Engine under light loads.

ORTON G. DALE. BEATTIE A. INGLIS.
JOHN F. PAULSEN. ANSON G. WILBOR.
Determination of the Heating Powers of Coals by means of the Mahler Calorimeter.

WILLIAM Y. DEAR. EDGAR G. SEAMAN.
Design of a Flat Bed Printing Press.

EDWIN R. DOUGLAS. WINTHROP S. FANNING.
Design for a Hull of a Steel Steamer, for Merchant Marine, for 15 knots per hour.

FRANKLIN D. FURMAN. MORS O. SLOCUM.
Electrical Horse-Power consumed by a Motor Car under varying Conditions, Newark, N. J.

JAMES A. GOLDSMITH. WILLIAM H. H. ROBERTS, JR.
The Latest Developments in the Mechanical Testing of Portland Cement.

HAROLD E. GRISWOLD. WM. PERCIVAL MACKENZIE. ADOLPH G. HUPFEL.
Test of the New York Hygeia Ice-Making Plant.

EDWARD A. HUPPERTZ. J. RENWICK WILKES.
Test of an Electric Motor and other Machinery for an Underground R. R. for a Mining Plant at Forrest City, Pa.

HENRY G. C. KOPP. FRED J. MEYSTRE.
Review and Experimental Determination of the rate of Transmission of Heat from Steam to Water through Metallic Coils.

THEODORE S. LEONHARD. EDWARD D. LEWIS.
Descriptive Test of two Armington and Sims Engines for Electric Lighting, at Ward's Island.

FRANKE L. PARKER. RUDOLPH RIEGE.
Comparison of Insulating Materials for Cold Storage.

CHARLES P. RITTENHOUSE.
High Potentials with Alternating Currents.

GEORGE L. WALL. FRED H. WOOD.
The Comparative Efficiency of Cable and Electric Systems as determined from Tests on the Elevated Division of the North Hudson County Railway Company, Hoboken, N. J.

Mr. F. D. Furman, the Valedictorian of the class, then made the parting address as follows:

Mr. President, Members of the Faculty, Trustees, and Friends: The goal of ambition is reached, only by passing through a succession of periods, in their natural order of sequence. We have just passed through one of these periods, perhaps the most important of all; for, is not the foundation of the building and the material thereof its most important constituent? The material has been furnished us, and we have built, as best we could, the foundation of a structure that we hope will be built up and perfected more and more as time goes on, and that the day is not far distant when we

shall be in possession of a structure of the mind that will give a habitation to our bodies so long as life lasts. To-night these foundations are to be solemnly dedicated before the world by those who have guided their construction, and it is an unspeakable joy which we feel that so many of our loved ones and friends have assembled here to show their appreciation and sympathy.

If you could stand here now, as I have the honor of doing, you would not only know and feel, but you could plainly see by the uniformity of joyful expression that the mingled sentiments of love and approbation are filling the souls of all to overflowing, while our cup of joy and pride, seasoned with sorrowful thoughts of parting, is filled to the brim. But further thoughts of sad sentiment, so abundantly suggested by this parting scene, must be reserved for the present, while your attention is invited for a few moments to some thoughts which may well occupy the mind of one who has pursued a scientific course of study.

Several years ago, while contemplating a collegiate course, I was surprised to read from the pen of so eminent a man as Ralph Waldo Emerson these words: "One of the benefits of a college education is to show a man how little he knows." It seemed as though a graduate must know all worth knowing in his profession when, diploma in hand, he stepped out from college into the world, but as the ladder of knowledge has been climbed, round after round, and the heights reached which have this day been attained, one finds himself in another realm, with a magnificent horizon, indefinitely extended, and the truth of those words, at first so paradoxical, is apparent. This view is unknown to the Freshman, it begins to dawn on the Sophomore, it is focused on the Junior, and has complete possession of the Senior by the time he has received his diploma. I have heard one of the greatest living physicists, who is on this platform to-night, and who, I am sure, will pardon me for being personal, confess in such words as these: "I don't know much, there's so much to learn." Coming from Professor Mayer, these words are significant and fit to dwell on; but we must

pass on to other thoughts which are continually bubbling up from the Pierian spring.

During the past four years it has been our privilege to study one of the divisions of science which is absolutely exact. There are no sects in a mechanical science; no warring schools contend here as in medicine; and why? Because a real science follows but one course, and that course flows only through the valley of truth. Where two opposing methods exist for the accomplishment of a common result, there you may rest assured is a lack of exact knowledge. In this respect the study of mechanical science is of inestimable worth as a training for the mind. It gives precision and definiteness, substitutes ideas of uniformity for those of caprice, and destroys the delusion that truth is to be arrived at by speculative methods.

The story of science is the history of a concentrated effort to discover and to devise something new and beneficial to mankind, and to perfect such discoveries or devices as are already made. Such perfecting of useful inventions furnishes us with the practical view of science which affords a sure prospect of speedy remuneration; but the view which far transcends this in beauty of thought and nobleness of purpose is the view of the searcher and the delver, seeking nature's mysteries, for our comforts, regardless of the consideration of personal profit.

This leads us to ask, what are nature's mysteries? How does it come that, in nature, law and order reign everywhere supreme? Nowhere can chaos be found! All materials, and all forces, from the very central atom of our earth to the very remotest particle of star dust in the infinitude of space, are governed by interacting laws, infinite in their number, marvelous in their expanse, incredible in their perfection. Such are nature's mysteries. Does it take long for you to pronounce the name of Him, of whose infinite intelligence and power these laws and materials are the expression? Unknown laws and materials exist. We must discover them. All praise to the pioneer in such discovery! Justly does glory cover

and honor crown such men as Galileo, Torricelli, Harvey, Kepler, Newton, and many others. How divinely happy Kepler must have felt when he reflected on the laws of planetary motion, which he had discovered, and cried out, in his awe, "Now, Oh God! think I Thy thoughts after Thee." The resources of the Creator are infinite. Nature is full of His secrets; and, in spite of the comforts of our life, and the luxury of our surroundings, who doubts but that we are only beginning to find them out? Who dare prophesy what the next century will bring forth? May not the electric light and the railroad of this century be the candle and stage coach of the next?

The thoughtful study of science is one of the most sublime approaches by which the human mind can reach the perception of the universal presence of a Deity; and suggests many things pleasing to dwell on; but time flies, and the words of parting, which must be sorrowfully said, cannot be deferred.

Mr. President: It is not for mere form's sake that I now turn to bid you, on behalf of my classmates, an earnest and solemn farewell. In the discharge of your onerous duties, you have daily presented to us an example of Christian piety, of a high-toned and honorable bearing, and of real excellence in scholarship. We have ever recognized in you the strict disciplinarian, the faithful instructor, and the kind friend. We would have you know that we appreciate the advantages which have come to us as a result of your many generous donations, which have gone far towards making Stevens one of the leading technical schools of the world; but there is yet room for further development, and we trust that the time is not far distant when Stevens will be generously remembered, so that your ever ready plans for a model scientific institution may be fully realized, and that you shall no longer be left to continue this noble work single handed. Our debt of gratitude is indeed beyond payment. We believe, however, that you will feel in some degree recompensed for the care and anxiety which the supervision over so many youths must necessarily entail, when you find that the principles you have inculcated have taken root and yielded an abundant harvest of

noble thoughts and generous deeds. Of the twenty classes which have already gone forth, none ever cherished a more ardent attachment for Alma Mater, or more fervently wished it prosperity than that which now bids you a respectful and affectionate farewell.

Gentlemen of the Faculty: Another class now presents itself to speak the parting word, and again the influence of your instruction is to be felt throughout this widely extended country. Yours has been a noble mission. You have not worked on mere matter, perishable as the sod we tread, but upon the living mind, "whose thoughts wander through eternity," and which is capable of recognizing its benefactors and offering the tributes of deserved gratitude. The fruits of your labors are not to be seen in palpable forms. They are to be found at the foundation of the blessings we enjoy. By you the great volume of nature has been unfolded and its mysteries interpreted. Many words of kindness, whose value we have not failed to appreciate, have mingled with your teachings. We go forth with this as our highest and noblest ambition—that we may become more and more like you, and that the day may come when we shall be able, as you are now, to look back upon lives spent under the guidance of truth and in the service of mankind. Farewell!

Fellow Students: The tie which has bound us together as members of the same scientific institution, for the last one, two, and three years, is now to be broken; but the friendship which has grown up between us will not cease to exist with a mere change of location. Our forms, it is true, shall so no longer be recognized in the college halls, and our voices shall no longer be heard in the hearty swelling chorus to Alma Mater, but there collection of our pleasant intercourse we shall ever fondly cherish. We leave you in possession of rare opportunities for mental and moral culture—opportunities which, if properly appreciated, will enable you to go forth from this cloistered home, full of hope, full of confidence, full of strength. Let the weak points of the armor which we have on be a warning to you while yet in the process of your preparation. In the midst

of your rivalries recollect that the memories of a harsh word or unkind act will increase tenfold the sorrow you will feel at parting with each other. We bid you all a sad farewell.

My Classmates: Four years ago, coming from differents parts of the world, representing various shades of opinion and character, we met in Stevens as strangers; but similar duties and common objects of interest and affection have made us friends. That moment, so long looked for, yet so sorrowfully thought of, has at length arrived, and we now pause to cast one look back on the past —its crowded associations, its bright pictures, its heartfelt griefs— ere we speak that word which shall break asunder the golden bands which have so long held us together in class fellowship.

The solemnity which hangs over this occasion is deepened by the reflection that many who were once, and others who still are, of our number, are not with us to-night. Some have already engaged in the active pursuits of life, and to these we would send a word of cheer— a hearty God-speed. One whose form was once as full of life, whose hopes were as bright as yours, had thought to stand with us to-night and breathe these parting words; but in the full glow of youth, in the pride of a cultivated and powerful intellect, in the hopefulness of manly promise, Robert L. Ryker was taken from "time to eternity." He has passed from us into the dark house and narrow valley in the full assurance of a brighter home beyond the portals of the tomb. In this sad bereavement is written the history of life; and, my classmates and friends, let not its lesson escape you. In coming years, should the class of '93 assemble under pleasant shades, others of us may not be present to answer to our names, and finally, when the time shall come that only a few old men with frosted locks are left, may youthful blood thrill their bended forms, merry gleams twinkle from their failing eyes, and approving smiles play on their lips, as they tell of good deeds performed and merited honors won.

You need no advice from me to-night, nor do I feel like giving it to you. As you stand here side by side with the chosen friends

of four years' intercourse, I would rather let the tide of emotion flow freely from breast to breast, until love vivifies your feelings and warming hearts incite you to nobler deeds—till class fellowship, now rising to its zenith, shall stand over this parting scene like the noon-day sun, and dispel every cloud of ill that may be hovering about us, and melt every strain of college strife into an emulation for future honors in which we shall all feel a common pride. If, in the midst of this parting, a tear should start unbidden as we look on some familiar face which to-morrow may be gone; or listen to some familiar voice, and think that many a year may pass before we hear it again, we will wipe such tear away, not as a weakness, but as a proper tribute to the day and occasion. It is hard to say farewell; but parents and friends are waiting to receive you with open arms and chase away the sadness of parting with your classmates, in a joyful welcome home to the scenes of your childhood. Go to meet them, and God go with you all—FAREWELL!

FRANKLIN D. FURMAN.

A reception to the graduating class was given on June 20 by Alpha XI, of Chi Psi Fraternity.

The Rho Chapter of Delta Tau Delta Fraternity gave an afternoon tea on June 22.

After the close of the Commencement Exercises a large number of the students and their friends were most hospitably and pleasantly entertained at the home of the Messrs. Cuntz.

ALUMNI MEETING.

The seventeenth annual meeting of the Alumni Association of the Stevens Institute of Technology, was held in the Hall of the Stevens School, at Hoboken, N. J., on the evening of June 21, 1893. The meeting was called to order at 8.30 o'clock by the President, Mr. C. J. Field.

The minutes of the previous meeting were read in abridged form, and, on motion duly made, seconded and carried, were approved as read.

Election of officers being in order, the President appointed Messrs. Humphreys and Wetzler tellers. The President then announced that the Executive Committee had decided that it would require a majority of the votes cast to elect to office, and that the members of the Class of '93 who had just been elected members of the Association, not having received their diplomas, would not be permitted to vote unless this decision should be overruled on appeal. No appeal was taken. The balloting then proceeded.

The report of the Treasurer, Mr. W. H. Bristol, was read and approved, the following balances being on hand—namely:

General Fund	$86.85
Beneficiary Fund	809.61
Library Fund	114.75
Portrait Fund	1.72
The Stevens Indicator	368.26

The Corresponding Secretary, Mr. P. E. Raqué, reported the receipt of the resignations of Messrs. H. F. Dawes, Albert Spies, '81, and C. W. Thomas, '84. The letters of these gentlemen were read. On motion duly made, seconded and carried, the resignation of Mr. H. F. Dawes was accepted. On motion duly made, seconded and carried, the resignation of Mr. Albert Spies was rejected. On motion duly made, seconded and carried, the resignation of Mr. C. W. Thomas was rejected.

The Treasurer of the Alumni Building Fund, Professor Riesenberger, reported that $8,240 had been paid in, and was bearing interest. On motion duly made, seconded and carried, the report was accepted.

The report of the Special Committee on Constitution was read, and, on motion duly made, seconded and carried, received.

The President then announced that Mr. Edward B. Wall had been elected Alumni Trustee to succeed Mr. William Kent. Mr. Kent, the retiring Trustee, then made a verbal report for the Alumni Trustees. On motion duly made, seconded, and carried unanimously by a rising vote, the report was accepted, and the thanks of the Association were tendered Mr. Kent.

The President then made a statement explaining the process by which the candidates for the office of Alumni Trustee had been selected.

The President then read his address to the Association, the subject being "The Electrical Engineer and His Relation to Mechanical Engineering." At the conclusion of the address, on motion duly made, seconded, and carried unanimously by a rising vote, the address was ordered printed in the INDICATOR, and the thanks of the Association were tendered the President.

President Morton, of the Stevens Institute, addressed the meeting, the subject being "The Alumni Building Fund and the Condition and Needs of the Institute." On motion duly made, seconded and carried, a vote of thanks was tendered to President Morton for his address.

The tellers then reported that Mr. Durand Woodman had been elected Vice-President, Mr. W. H. Bristol Treasurer, and Mr. Joseph A. McElroy a Director; also that there was no election for President, Recording Secretary, Corresponding Secretary, and the other Director. Another ballot for these officers was ordered.

Remarks were then made by Professors Wood, Denton and Webb. Professor Wood, among other things, said "that the greatest need of the Institute is a well-disposed dead man." Professor Denton

explained the reason of the delay in the issue of the April INDICATOR, and gave some incidents relative to the theses of the graduating class. Professor Webb said that the Senior Class complained that it was all right on *theory*, but that it was the *condition* which bothered it.

The tellers again reported that there was no election.

On motion duly made, seconded and carried, Mr. William Sheldon, who had received the highest number of votes for that office, was declared elected to the office of Director.

On motion duly made, seconded and carried, Mr. P. E. Raqué, who had received the highest number of votes for that office, was declared elected to the office of Corresponding Secretary.

A further ballot for the offices of President and Recording Secretary was ordered.

On motion duly made, seconded and carried, the report of the Committee on Constitution was taken up for discussion.

On motion duly made, seconded and carried, speeches were limited to three minutes, no member to speak more than twice on the same subject.

On motion duly made, seconded and carried, the proposed Constitution was read by sections for amendment, the headings only being read, unless the text was called for, and the sections, as follows, were approved—namely:

ARTICLE I.

NAME.

This Association shall be known as the Alumni Association of the Stevens Institute of Technology.

ARTICLE II.

OBJECT.

The object of this Association shall be to cultivate such social relations as shall tend to foster among its members a sentiment of regard for one another, and of attachment to their Alma Mater, and to promote, in every way, the interests of the Institute.

ARTICLE III.

MEMBERSHIP.

SECTION 1. All recipients of degrees from Stevens Institute of Technology are eligible to Active Membership in this Association, and only such Active Members shall have the right to vote.

SEC. 2. All students who may have voluntarily severed their connection with the Institute in their Junior or Senior years, may be elected to Associate Membership in this Association.

SEC. 3. All members of the Faculty, not eligible for Active Membership, shall be, *ex officio*, Honorary Members of this Association.

SEC. 4. Associate and Honorary Members shall have all the privileges of membership except in regard to nominations, voting, and holding offices.

SEC. 5. (*a*) The names of candidates for Active and Associate Membership shall be presented in writing to the Recording Secretary previous to the opening of the Alumni meeting at which they are to be proposed.

(*b*) Candidates may be elected to membership, by ballot, at any regular meeting of the Association. Candidates for membership from the graduating class of any year may be elected by ballot by the Executive Committee in advance of the annual meeting of that year. Members of the graduating class when elected shall enjoy all of the privileges of Associate Membership until they shall have graduated and received their degrees, whereupon they will be promoted to Active Membership, without further action on the part of the Association.

(*c*) A vote of three-fourths of all members, Active and in good standing, present either at a meeting of the Association or at a meeting of the Executive Committee, shall be necessary for election to membership.

ARTICLE IV.

OFFICERS.

SECTION 1. (*a*) The officers of this Association shall be a President, a First Vice-President, a Second Vice-President, a Corresponding Secretary, a Recording Secretary, a Treasurer, and the Alumni Trustees.

(*b*) All the above officers, with the exception of the Alumni Trustees, who shall hold office for three years, shall be elected for a term of one year, in the manner hereinafter provided for.

(*c*) There shall be four Directors, two of whom shall be elected each year (in the manner hereinafter provided for) for the term of two years.

SEC. 2. (*a*) No member shall be eligible for election to the Presidency of this Association unless he be a graduate of at least seven years' standing, and no member shall be eligible for election to any of the other offices, or to directorship, unless he be a graduate of at least three years' standing.

(*b*) The President of this Association shall not be eligible for immediate re-election to that office.

SEC. 3. (*a*) The President shall preside at all meetings of the Association and of the Executive Committee.

(*b*) He shall, with the Recording Secretary and the Treasurer, sign all written contracts and obligations of the Association.

(*c*) He may call special meetings ot the Executive Committee, and must do so at the written request of three of its members. He shall call special meetings of the Association whenever so requested by resolution of the Executive Committee, or by the written request of fifteen Active Members in good standing.

(*d*) He shall perform such other duties as may be assigned him by the Executive Committee.

SEC. 4. The First Vice-President, or, in his absence, the Second Vice-President, shall assist the President, and shall discharge the duties of the President in the event of his absence, or during a vacancy in the office.

SEC. 5. (*a*) The Corresponding Secretary shall conduct the correspondence of the Association not otherwise provided for, and shall send ballots to each member as hereinafter provided.

(*b*) He shall issue calls for all meetings, regular or special.

SEC. 6. The Recording Secretary shall—

(*a*) Keep the minutes of all meetings of the Association and of the Executive Committee.

(*b*) He shall notify members of their election.

(*c*) He shall have the minutes and records of the Association ready for inspection at all times by the Executive Committee, and by any member of the Association.

(*d*) He shall send to the Treasurer the names and addresses of all persons elected to membership.

(*e*) He shall keep a correct list of the names and addresses of all members of the Association, and shall furnish the Corresponding Secretary a copy of the same, and keep him properly informed of all corrections.

SEC. 7. The Treasurer shall—

(*a*) Have the custody of the funds of the Association.

(*b*) He shall collect all dues; send out notices as called for in Art. IX.; pay all bills contracted by the Association, and keep full and correct records of all receipts and disbursements.

(*c*) He shall make a report of the financial condition of the Association at each regular meeting of the Executive Committee, and at the annual meeting of the Association.

ARTICLE V.

THE EXECUTIVE COMMITTEE.

SECTION 1. The officers, together with the four Directors, shall constitute the Executive Committee.

SEC. 2. (*a*) The Executive Committee shall have the general control and management of the affairs of the Association, subject to the direction of the Association.

(*b*) It shall receive the nominations for officers and prepare and send out ballots through the Corresponding Secretary, and canvass the same as hereinafter provided.

(*c*) It shall use its best endeavors to secure subscriptions for the Beneficiary Fund. It shall select the beneficiaries, as hereinafter set forth, and keep a record in full in its minutes of all agreements and contracts with the said beneficiaries.

(*d*) It shall, at its discretion, make provision for appropriate exercises and entertainments at all meetings of the Association.

(*e*) It shall audit all bills of the Association.

(*f*) It shall present a complete report of its work at each annual meeting of the Association.

(*g*) Six of its members shall constitute a quorum.

SEC. 3. (*a*) Regular meetings of the Executive Committee shall be held between the 1st and the 10th days of the months of January, April, May, June and October in each year, at such time and place as it may appoint, and special meetings when called by the President.

(*b*) Six of its members shall constitute a quorum.

SEC. 4. In the case of a vacancy occurring in the Executive Committee, that committee shall, at its next meeting thereafter, appoint a member to the vacancy, who shall hold office until the next annual election. This section shall not apply to vacancies in the office of Alumni Trustee.

ARTICLE VI.

ELECTIONS.

SECTION 1. All officers and Directors shall be voted for by sealed letter ballot.

SEC. 2. All Active Members of the Association in good standing shall have the right to nominate and vote for candidates for officers and Directors of the Association, except for candidates for the office of Alumni Trustee, which is hereinafter provided for.

SEC. 3. (*a*) Nominations for officers and Directors (except Alumni Trustees), may be made in writing over their own signatures by any three members, and nominations so made shall be sent to and received by the Executive Committee not later than the 1st day of April in each year, and no nominations received by the Executive Committee after that date shall be considered.

(*b*) The Executive Committee may name a ticket, and it shall be its duty to do so if no other complete list of nominations be received by April 1.

SEC 4. (*a*) The Executive Committee through the Corresponding Secretary shall, on or before the 20th day of April, send to each Active Member of the Association a ballot bearing the names of all the nominees for each office, together with a blank envelope, and an envelope addressed to the Corresponding Secretary of the Association.

(*b*) The Active Member desiring to vote shall erase from this ballot the names of all the nominees except those for whom he wishes to vote.

(*c*) He shall put the ballot so prepared into the blank envelope, and enclose the latter in the addressed envelope. He shall endorse his name and address across the back of the addressed envelope and mail the same

to the Corresponding Secretary, and no ballot shall be canvassed by the Executive Committee unless the envelope is so endorsed.

(*d*) The ballots so prepared must be in the hands of the Corresponding Secretary on or before the 1st day of June, and no ballots received after that date shall be counted.

SEC. 5. (*a*) It shall be the duty of the Executive Committee to convene not later than one week previous to the annual meeting, for the purpose of counting the ballots so received. The nominee receiving the highest number of votes for each office shall be declared elected, and the result of this election shall be announced at the annual meeting.

(*b*) In the event of a tie vote for any office, the Executive Committee, by a majority vote of its members present, shall determine which of the nominees so tied shall receive the office, and the Executive Committee shall report at the annual meeting the names of those so tied.

SEC. 6. (*a*) Candidates for the office of Alumni Trustee must be Active Members in good standing, graduates of not less than ten years, and not members of the Faculty or of the Board of Trustees. They shall be chosen at the time of the election of the other officers of the Association, and in the same manner.

(*b*) Each alumnus who is an Active Member of the Association, in good standing, and who has been graduated at least two years, shall have the right to nominate and vote for one candidate for each vacancy in this office.

(*c*) The Executive Committee shall canvass the ballots for Alumni Trustee, and shall report to the Board of Trustees three names for each vacancy, reporting the names of those receiving the highest number of votes in order as voted, and stating the number of votes received by each. From these candidates the Board of Trustees will elect to fill the vacancies.

(*d*) The result of the election of candidates for Alumni Trustee, together with the number of votes received by each, shall be announced at the annual meeting, immediately after the announcement of the result of the election of other officers of the Association.

SEC. 7. Alumni Trustees shall not be eligible for immediate re election.

SEC. 8. It shall be the duty of the Corresponding Secretary to mail to each Active Member of the Association, not later than the 1st day of March in each year, a notice stating what officers are to be elected, and asking for nominations.

ARTICLE VII.

DUES AND THEIR COLLECTION.

SECTION 1. The yearly dues shall be $2.50, payable by each Active and Associate Member on or before the 1st day of January in each year, and this payment also entitles each member to one copy of every issue of the INDICATOR for the current year.

SEC 2. The Treasurer shall, on or before the 3d day of December in each year, mail to each Active and Associate Member a notice stating the amount of his dues for the succeeding year, and his arrears, if any, with a request for payment. (See Art. IX.)

SEC. 3. When the dues of any member remain unpaid for a period of three months after they become due, the Treasurer shall mail to such member a notice that, unless said dues be paid within two months from date of said notice, such member shall be deemed not in good standing, and shall be deprived of his right to hold office, to make nominations, to vote for officers or at meetings of the Association, and the INDICATOR shall cease to be mailed to him. If payment be not made within the time so fixed his privileges shall be so suspended and shall so remain suspended until payment in full is made.

SEC. 4. (*a*) Any member in arrears for dues for three consecutive years, unless payment in full be made before the expiration of the two months specified in the third year's notice, as provided for in Sec. 3 of this Article, shall cease to be a member of the Association, and it shall be the duty of the Recording Secretary to drop his name from the rolls of the Association without further action of the Association or of the Executive Committee. The names of all members so dropped shall be announced at the next annual meeting thereafter in the report of the Treasurer.

(*b*) Any member so dropped may be reinstated by the Executive Committee on the payment of all back dues with interest.

SEC. 5. Any member elected during the year shall pay dues proportioned to the unexpired term of the year, but he will not be entitled to a copy of the INDICATOR for that year unless he pays a full year's dues.

SEC. 6. No assessments for any cause whatever shall be levied.

SEC. 7. A copy of this Article shall be printed on all bills and notices provided for therein.

ARTICLE VIII.

BENEFICIARY FUND.

SECTION 1. (*a*) The Beneficiary Fund shall receive all contributions from members and friends of the Association which the donors desire to devote to the development of the beneficiary system.

(*b*) The Executive Committee may from time to time, as circumstances warrant, appropriate moneys from the General to the Beneficiary Fund.

SEC. 2. Accurate detailed accounts of the accession to and disbursements from this fund shall be kept by the Treasurer, under the direction of the Executive Committee, as per Art. IV., Sec. 9, paragraph (*c*).

SEC. 3. (*a*) This fund shall be administered under the direction of the Executive Committee for the purpose of assisting deserving students in their Institute career.

(*b*) A promissory note for value received shall, in all cases, be exacted of each beneficiary.

(*c*) When a beneficiary leaves the Institute he shall give one promissory note for value received, which shall include his entire indebtedness to the fund, and retire all outstanding notes.

ARTICLE IX.

MEETINGS AND RULES.

SECTION 1. (*a*) The annual meeting of the Association shall be held some time during Commencement week, at Hoboken, date and hour to be at the discretion of the Executive Committee.

(*b*) The meeting shall preferably be held at the Institute, but should this be inconvenient, the Executive Committee shall designate a suitable place.

SEC. 2. The semi-annual, or winter meeting of the Association, shall be held in January or February of each year, in the evening, the date and place for holding the same to be selected by the Executive Committee.

SEC. 3. Special meetings may be called as per Art. IV., Sec. 4, paragraph (*c*), and the place and time for holding same, with the reasons for so doing, shall be stated in the notice of the meeting, a copy of which notice shall be sent to each member. No business shall be transacted at a special meeting other than that specified in the notice of the meeting.

SEC 4. Notices of all meetings must be mailed at least two weeks before the date of proposed meeting.

SEC. 5. (*a*) Twenty-five members in good standing shall constitute a quorum at any regular or special meeting of the Association. Voting by proxy shall not be permitted.

(*b*) Active Members in good standing, present at any meeting, and not voting, shall be deemed constructively present for the purpose of forming a quorum.

SEC. 6. (*a*) The order of business at all meetings of the Association shall be as follows:

1. Opening of meetings and noting presence of a quorum.
2. Reading, correction and approval of minutes of previous meetings.
3. Reports of officers.
4. Reports of committees.
5. Proposal and election of new members.
6. Unfinished business.
7. General business.
8. Announcement of the result of the election of officers, members of the Executive Committee and Alumni Trustees.
9. Appropriate exercises and entertainments.
10. Adjournment.

(*b*) The rules for conducting all debates shall be as per Robert's Rules of Order.

ARTICLE X.

NOTICES.

SECTION 1. Each member shall promptly notify the Recording Secretary of any change in his address, and all notices, bills for dues, etc., shall be sent to the latest address sent by such member.

SEC. 2. Members shall be held to have received notices two weeks after the same have been mailed as above provided. [See also Art. IV., Sec. 5, (*a*) and (*b*); Sec. 6, (*b*); Sec. 7, (*b*); Art. V., Sec. 2, (*b*); Art. VI., Sec. 4, (*a*); Sec. 6, (*a*); Sec. 8; Art. VII., Sec. 2, 3, 4, (*a*); Art. IX., Sec. 3, 4; Art. XI., Sec. 2; Art. XIII., Sec. 2, (*c*); Sec. 3, (*c*).]

ARTICLE XI.

DISCIPLINE AND COMPLAINTS.

SECTION 1. Any member or members having a complaint to make against any other member or members, for any infraction of the rules of the Association, or for conduct injurious to the welfare of the Association, shall report the same in writing to the Executive Committee.

SEC. 2. After receiving such complaint, which must set forth the facts of the case, together with the names of witnesses, if any, a meeting of the Executive Committee shall be held as soon as practicable to investigate the same. Of such meeting the member or members complained of, and the member or members making the complaint, shall receive at least ten days' notice and may then be heard. The Executive Committee after investigation, shall report their findings, together with their recommendations, to a special meeting of the Association called for that purpose, or to the next regular meeting, as the Executive Committee may, in its discretion, find advisable. The decision of the Association shall be final.

ARTICLE XII.

THE STEVENS INDICATOR.

SECTION 1. (*a*) THE STEVENS INDICATOR shall be the official organ of this Association, and a record of every meeting of the Association, properly revised by the Executive Committee, together with official reports in full, shall be published in the next issue of the INDICATOR following said meeting.

(*b*) The Executive Committee may from time to time, at its discretion, publish in the INDICATOR such reports of its transactions as it may deem of general interest, and which it may desire to bring to the attention of the Association.

SEC. 2. The Executive Committee shall appoint the Alumni editors of the INDICATOR as vacancies occur, and may, at its discretion, remove such editors for inefficiency, or for malfeasance in office.

SEC. 3. The Alumni editors of the INDICATOR shall receive such compensation as may be fixed by the Executive Committee.

SEC. 4. The Alumni editors, aside from their strictly editorial duties in connection with the undergraduate editors, shall keep themselves well informed on current topics of particular interest to the Alumni, with the view of spreading such information in the columns of the INDICATOR. They must be in communication with the Executive Committee for the purpose of promptly publishing its minutes, transactions, communications, recommendations, etc.

ARTICLE XIII.

AMENDMENTS.

SECTION 1. (*a*) A proposed amendment to this Constitution shall be presented and seconded at either an annual or a midwinter meeting.

(*b*) The proposer and the seconder may, at the time of presentation, make statements of the arguments in favor of its passage, but it shall not be thrown open to general discussion.

(*c*) The proposed amendment shall then be referred to the Executive Committee for its recommendation.

SEC. 2. (*a*) The Executive Committee, previous to the publication of the minutes of the meeting at which the amendment was proposed, shall carefully consider the merits of the case, and then cause to be printed in the INDICATOR, in connection with the minutes, a full record of the proposal and the statements accompanying the same.

(*b*) The Executive Committee may also include in said publication its own recommendation in the premises, and, if it so desires, may recommend a substitute for the amendment as proposed.

(*c*) The notices for the next meeting (annual or midwinter, as the case may be) shall contain the full text of the amendment as proposed, and the Executive Committee's substitute therefor, if any, together with the announcement that the proposed amendment will come up for discussion at said next meeting.

SEC. 3. (*a*) At this next meeting the amendment, so proposed, shall be open to general discussion.

(*b*) The proposed amendment in its final form, as resulting from this discussion, shall be published, together with a full record of its discussion, in the issue of the INDICATOR containing the minutes of this second meeting.

(*c*) The Corresponding Secretary shall, thereafter and before the next regular meeting, mail to each Active Member of the Association a ballot bearing the full text of the proposed amendment. If the next meeting is to be an annual meeting, this ballot shall be mailed with the ballot for officers, on or before the 20th of April, as provided for in Art. VI., Sec. 4, (*a*); if the next meeting be a midwinter meeting, the amendment ballot shall be mailed not later than eight weeks before the time set for said meeting.

(*d*) Each Active Member may vote in the negative as to each and every form in which the amendment is proposed, but he can only vote in the affirmative as to any one form of said amendment.

(*e*) He shall prepare and mail his ballot in the manner set forth in Art. VI., Sec. 4, (*b*) and (*c*), and no ballot shall be canvassed by the Executive Committee unless so prepared.

(*f*) In the case of the next meeting being an annual meeting, the ballots so prepared must be in the hands of the Corresponding Secretary on or before the 1st day of June, and no ballots received after that date shall be counted.

(*g*) In the case of the next meeting being a midwinter meeting, the ballots so prepared must be in the hands of the Corresponding Secretary not later than two weeks before the date set for the said midwinter meeting, and no ballots received after that time shall be counted.

(*h*) In the case of the next meeting being an annual meeting, the ballots so forwarded to the Corresponding Secretary shall be canvassed by the Executive Committee at the meeting at which the ballots for officers are canvassed.

(*i*) In the case of the next meeting being a midwinter meeting, the ballots so forwarded to the Corresponding Secretary shall be canvassed by the Executive Committee not later than the day previous to said meeting.

(*j*) It shall require two-thirds of all the votes so canvassed to carry an amendment to the Constitution.

SEC. 4. (*a*) The result of the ballot shall be announced in the Executive Committee's report at the next regular meeting following the canvass, and the amendment, if adopted, shall then go into effect.

(*b*) The official copy of the Constitution in the minute book of the Association shall at once be corrected in accordance with the action so taken.

ARTICLE XIV.

This Constitution shall take effect on July 1, 1893, at 12 o'clock, noon.

When Article XIV. had been read and approved, on motion duly made, seconded and carried, the Constitution as read and approved by sections, was approved as a whole.

On motion duly made, seconded and carried, it was ordered that the Executive Committee have the Constitution as adopted printed, and a copy sent to each and every member.

On motion duly made, seconded and carried, a vote of thanks was tendered to the Special Committee on Constitution, and that committee was discharged.

The tellers reported that Mr. J. Day Flack had been elected Recording Secretary, and that there was no election for President. A further ballot was ordered, at the conclusion of which the tellers reported that Mr. Harry Van Atta, '81, had been elected President, the vote standing 28 for Van Atta, 25 for Cronise.

On motion duly made, seconded and carried, the elections of Messrs. Van Atta and Flack were made unanimous.

On motion duly made, seconded and carried, the meeting then, at 11.20 o'clock P. M., adjourned.

C. J. FIELD,
President.

E. B. RENWICK,
Acting Recording Secretary.

MEMBERS IN ATTENDANCE.

President Henry Morton.
Prof. de Volson Wood.
" J. Burkitt Webb.
" A. R. Leeds.
" Edward Wall.
" J. E. Denton.
" Wm. E. Geyer.
" T. B. Stillman.
Ass't Prof. A. Riesenberger.
" Wm. H. Bristol.
" D. S. Jacobus.
" R. M. Anderson.
Wm. Kent, '76.
P. E. Raqué, '76.
A. P. Trautwein, '76.
A. R. Wolff, '76.
F. E. Idell, '77.
L. H. Nash, '77.
A. A. de Bonneville, '78.
Wm. Sheldon, '78.
D. Woodman, '80.
E. H. Cronise, '81.
A. C. Humphreys, '81.
J. Wetzler, '82.
M. McNaughton, '83.
E. H. Foster, '84.
W. L. Lyall, '84.
E. B. Renwick, '84.
B. H. Coffey, '85.
J. M. Rusby, '85.
Wm. N. Stevens, '85.
C. J. Field, '86.
W. L. Haynes, '86.
F. E. Jackson, '86.
J. H. Bates, '87.
R. N. Bayles, '87.
J. H. Cuntz, '87.
W. S. Dix, '87.
J. D. Flack, '87.
B. F. Hart, Jr., '87.
E. H. Kiernan, '87.
J. A. McElroy, '87.
W. E. Parsons, '87.
H. A. Bang, '88.
N. St. G. Campbell, '88.
G. Dinkel, Jr., '88.
P. Doty, '88.
E. Ducommun, '88.
B. P. Hall, '88.
J. V. L. Pierson, '88.
F. Uhlenhaut, '88.
D. H. Gildersleeve, '89.
P. C. Graupner, '89.
A. G. Mayer, '89.
J. S. de Hart, Jr., '90.
W. M. Farrar, '90.
D. C. Harvey, '90.
H. P. Jones, '90.
S. F. Smith, '90.
C. Trautvetter, '90.
E. H. Whitlock, '90.
A. P. Boller, '91.
S. L. G. Knox, '91.
L. H. Nettleton, '91.
J. A. Norcross, '91.
H. W. Smith, '91.
H. B. Atkins, '92.
W. C. Cuntz, '92.
H. Lowenherz, '92.
A. J. Post, Jr., '92.
W. E. S. Strong, '92.
A. E. Bruen, '93.
H. B. Cook, '93.
F. D. Furman, '93.
H. E. Griswold, '93.
W. P. Mackenzie, '93.
R. Riege, '93.
J. R. Wilkes, '93.

ATHLETICS.

BASE-BALL.

The season was opened on April 19 with Stevens *vs.* Columbia at Hoboken, the score standing Stevens 4, Columbia 3. On April 26 the return game was played on the Columbia grounds at High Bridge, when Stevens again won with a score of 6 to 3.

Stevens *vs.* Rutgers on May 11 at New Brunswick was another victorius game for our team: Stevens, 11; Rutgers, 1.

The games for April 21 with Manhattan College and May 13 with West Ends, at Somerville, were cancelled. That for May 3 with Rutgers was not played on account of stormy weather.

The members of the team and their positions are as follows: Cuming, c.; Paulsen, 2d b.; Fielder, l. f.; Decker, 1st b.; Kirker, 3d b.; Tarr, c. f.; Inglis, s. s.; Scott, r. f.; Corwin, p.

Considering the limited opportunities for practice, the team has put up excellent games with most creditable results. The base-ball team of 1893 has made a record which lovers of the national game among the Stevens graduates can refer to with entire satisfaction.

LACROSSE.

The unusual rainfall this spring kept the grounds in most unfavorable condition for practice, especially that limited portion of it available for lacrosse, which sadly interfered with team practice. The first game was played on May 5 against Cornell at Hoboken. The score was Stevens 3, Cornell 1. Stevens goals were made by Kellogg, MacCord and Hutchinson.

The game of May 10 with Princeton was another victory for Stevens, with a score of 4 to 2. Two goals were made by Kellogg and one by Maynard for Stevens.

Stevens *vs.* Lehigh at Hoboken on May 13 was a closely contested and exciting match. The team play of Lehigh was superb, winning them the game with a score of 6 to 3. Kellogg made two of Stevens goals and MacCord one.

The closing game of the championship lacrosse series was played with Johns Hopkins University at Baltimore on May 20. The Baltimore team were winners by a score of 6 to 3 after a well-contested game, in which, unfortunately, Stevens had been unable to enter all of the regular members of the team.

The championship held last year by Stevens has this year been deservedly won by Lehigh.

FIELD GAMES.

An innovation was tried this season, a joint field day with Rutgers having been arranged. The results of the contests clearly showed the necessity for a more thorough preparation on the part of Stevens' representatives in the future if they would equal the Rutgers athletes. Rutgers led by a total of 70⅓ points to 49⅔.

INSTITUTE NOTES.

CATALOGUES have this year been forwarded to each alumnus. Should any have failed to reach their destination, another will be mailed upon request made to the Secretary of the Institute.

THE BOARD OF TRUSTEES made an appropriation of $6,500 for the erection of a building to contain a dynamo room and a more commodious recitation room for the Department of Languages. This addition is located between the machine shop and the east wing of the Institute. It is two stories high, and is expected to be ready for occupancy by the beginning of the next term.

PROFESSOR KROEH'S present class room will be occupied as a drawing room by the upper classes in connection with the large eastern room. Thus the entire top floor of the Institute will hereafter be devoted to the Drawing Department.

PROFESSOR LEEDS will now take the lecture room formerly occupied by President Morton, and his recitation room will be converted into a chemical laboratory, thus doubling the space available for analytical chemistry.

A further alteration will be the conversion of the second floor of the shop wing into a recitation room for the Department of Experimental Mechanics, and an enlarged pattern shop, by removing the dynamos, etc., to the new building, and installing Mr. Hawkridge in the present pattern shop.

TWO NEW INSTRUMENTS were secured for the Institute this year by members of the graduating class. One, a Mahler Calorimeter for determining the heating power of fuels; the other, a Fairbanks Automatic Testing Machine for testing Portland cement.

AT THE ENTRANCE EXAMINATIONS in June there were 112 applicants. It is to be expected that many of those not sufficiently prepared will avail themselves of the time before the September examinations, and then try to enter. The indications are that the entering class will be so large as to necessitate division into two sections.

THE FACULTY has posted a new regulation which affects all conditioned students excepting those entering the Freshman year. This rule, which reads as follows,—

"All students having one or more conditions at the end of the third term (except in shopwork) are regarded as not advanced with their class, and will of course be obliged to repeat the year, unless they have made up their conditions before 4 P. M. on September 25, 1893. There will be no second re-examination,"—

has created an unusual degree of interest in preparation for the September re-examinations.

A RECORDING VOLTMETER for both direct and alternating currents has been perfected by Professor Bristol, who has also produced a new recording thermometer and pyrometer.

PROFESSOR DENTON has been appointed one of the Judges of Awards in Machinery Hall, and Chairman of the Committee on Boiler and Engine Tests, at the Columbian Exposition.

PROFESSOR GEYER has been appointed a Judge of Awards in the Electrical Department of the Columbian Fair.

PROFESSOR JACOBUS, Secretary of the Mechanical Section of the American Association for the Advancement of Science, has made energetic preparations, in conjunction with the Vice-President of the Mechanical Section, Prof. S. W. Robinson, to render the coming meeting at Madison, Wis., on August 16, an unusually interesting one, and has secured the promise of a number of valuable papers.

A 50 HORSE-POWER BALL & WOOD SIMPLE ENGINE has been loaned to the Department of Tests, for the purpose of making some special experiments in reference to the possibilities of inertia governors, the influence of different degrees of compression upon steam economy, and the determination of the water consumption when very lightly loaded, none of which points has been covered by experiments published to date.

A part of the data required for the solution of the last-mentioned problem has been obtained by Messrs. Cook and Lord, and has been successfully worked up by them in their graduating thesis, which will appear in the October issue of the INDICATOR.

It is expected that the results of investigations on the other two problems will be published later by Professors Denton and Jacobus.

THE THESIS of Messrs. Griswold, Hupfel, and Mackenzie is thought to contain the results of the most complete experimental investigation of the distribution of heat in all of the steps involved in the manufacture of artificial ice, of which any record is available. The writers will contribute it as a paper to the American Association for the Advancement of Science.

ORIGINAL DATA on the rate of transmission of heat through iron coils, were experimentally obtained by Messrs. Kopp and Meystre, in the preparation of their thesis.

AMONG the foreigners attracted to this country by the Columbian Exposition a very large contingent is likely to come from among educators in Europe. Already several of these distinguished gentlemen have called at the Institute on their route to Chicago.

MR. THEOBOLD BÖHM, consulting mechanical engineer, of Stuttgart, visited the Institute on the recommendation of Professor Schroeder, of Munich, and showed keen interest in the course of instruction, and made many direct and practical inquiries in reference to the experimental work done by the students. It was Mr. Böhm's intention to inspect the principal machine shops of this country.

MR. ALFRED LUTKEN, civil and mechanical engineer, and professor at the Royal Polytechnic College of Copenhagen, Denmark, was introduced by Mr. Braem, the Danish Consul at New York. He wished to see what is being done in a practical way by the Institute, and appeared very favorably impressed by our facilities and methods.

PROFESSORS O. E. WESTIN and Erik Anderson, of the Technical High School of Stockholm, Sweden, who were utilizing their vacation by visiting the Columbian Fair, have letters of introduction from the American Minister to Sweden.

They evinced great interest in the Department of Experimental Mechanics, the work of which they had an excellent opportunity of observing in progress, as the members of the Junior Class were, at the time, engaged in the various testing exercises of the Supplementary Term. Their inquiries indicated a thorough acquaintance with the subjects relating to the tests inspected, yet they found some of the apparatus employed both novel and interesting to them. Among these were the apparatus for determining the latent heat of anhydrous ammonia, that for measuring the quantity of heat radiated by a steam coil immersed in water, the Barrus Calorimeter, and the Bristol Recording Pressure Gauge. At their schools no practical work is undertaken by students, and the greater value of our course, due to these experimental exercises, was frankly recognized.

PROF. A. MARTENS, Director of the Royal Mechanical Laboratory for Technical Research, Berlin, who is visiting the principal technical schools of this country, spent a large portion of one day interviewing the professors and examining the methods of instruction here. The methods of analyzing and testing lubricating oils, on which subject he is an authority, engaged his interested attention. He spoke in favorable terms of the efficiency of the American system of instruction, as compared with that adopted in universities abroad, stating that while the former required a greater amount of labor on the part of the professors, it brings them into closer relations with the students, and induces greater average progress.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'76.

AT the annual meeting of the Westinghouse Electric and Manufacturing Company, held at Pittsburg, May 17, W. F. Zimmerman was elected Assistant General Manager of the Company.

EDWARD B. WALL has been appointed assistant to the First Vice-President of the Pennsylvania lines west of Pittsburg, with headquarters in the Brother Jonathan Building in Chicago. He is in general charge of the company's interests there, excepting only traffic.

'80.

GEORGE M. BOND has charge of the World's Fair exhibit of the Pratt & Whitney Company, of Hartford, Conn.

'81.

EDMUND P. LORD, until recently Superintendent of Motive Power, of the Cleveland, Chicago, Cincinnati and St. Louis Railroad, has accepted the position of General Manager of the H. K. Porter Company, builders of light locomotives, Pittsburg, Pa.

'82.

VERNON H. ROOD, Superintendent of the Jeansville Iron Works, of Jeansville, Pa., has been granted a patent for a coal jigger, No. 490,793, June 31, 1893.

MRS. R. H. WHITLOCK, wife of Prof. R. H. Whitlock, died at College Station, Tex., on Wednesday, July 19, 1893.

'83.

MALCOM MCNAUGHTON has charge of the World's Fair exhibit of the Joseph M. Dixon Crucible Company, Jersey City, N. J.

'84.

S. P. BUSH is now Acting Superintendent of the Pittsburg, Cincinnati and St. Louis Railroad, and of the other affiliated roads of the Pennsylvania Company's southwest system.

H. L. GANTT, late of the Midvale Steel Company, Nicetown, Pa., has been appointed General Superintendent of the American Steel Wheel Company, and as such will have charge of the new plant at Garwood, N. J.

H. DE B. PARSONS has been appointed to supervise the construction of the new steel twin-screw steamer for the New York Harbor police. The steamer will be equipped with steam steering apparatus, an electric light plant, a search light, and powerful pumps for fire and wrecking purposes.

WILLIAM S. ALDRICH is Professor of Mechanical Engineering and Director of Mechanic Arts at the West Virginia University, Morgantown, W. Va.

Professor Aldrich has submitted plans, estimates and specifications for a new foundry addition and a mechanical laboratory, which will probably be erected this summer.

HARVEY H. MITCHELL has resigned his position as Instructor in the College of the City of New York, and is now Secretary and Treasurer of the Everett Transportation and Commercial Company, Everett, Wash.

'87.

LARZ W. ANDERSON has resigned his position as Superintendent of the Addyston Pipe and Steel Company, and accepted a position with the J. A. Fay & Egan Company, manufacturers of wood working machinery, Cincinnati, O. At the present time he has charge of the installation of the exhibit of the company at the World's Fair.

WALTER S. DIX is Chief Draughtsman for the Crocker-Wheeler Electric Company, Ampère, N. J.

'88.

EDWARD DUCOMMUN is Assistant Engineer in the American Sugar Refining Company, Jersey City, N. J.

ARTHUR L. SHREVE was married on June 7 to Miss Harriet Rebecca Gale, at St. Paul's Church, Baltimore, Md.

'89.

J. R. ONDERDONK is located in the office of Engineer of Tests of the Baltimore and Ohio Railroad, Mt. Clare, Baltimore, Md.

'90.

E. H. WHITLOCK is Manager of the New York Oxygen Company, First Avenue, near Twenty-first Street, New York City.

'91.

GEORGE L. MANNING was married on June 19 to Miss Alice Washburn Heald, daughter of Mr. Daniel Addison Heald.

'92.

N. H. HILLER will be in Los Angeles, Cal., for the next six months in the interests of the Hendrick Manufacturing Company, of Carbondale, Pa., with which he is connected.

E. D. LITCHFIELD is in the employ of the Philadelphia Car Wheel Company, manufacturers of railroad and street car wheels, Snyder Avenue and Swanson Street, Philadelphia, Pa.

GEORGE H. MILLER was married to Miss Harriet E. Griswold, at West Orange, N. J., on June 1, 1893.

'93.

R. E. CHANDLER is connected with the Snow Steam Pump Works, Rosser and Snow Avenues, Buffalo, N. Y.

EDWIN R. DOUGLAS is connected with the Howe Scale Company, Rutland, Vt.

CHARLES T. BAYLESS is with D. L. Barnes, consulting engineer, 768 The Rookery Building, Chicago, Ill.

BANCROFT G. BRAINE is with Thomas E. Brown, consulting engineer for Otis Elevator Company, 114 Nassau Street, New York City.

B. B. BRISTOL is connected with the Bristol Manufacturing Company, Waterbury, Conn.

FRANKE L. PARKER is in the employ of the Capefair Harbor and Coal Company, Charleston, S. C.

J. RENWICK WILKES is in the employ of the Trenton Iron Company, Trenton, N. J.

BOOK NOTICES.

ACCESSIONS TO INSTITUTE LIBRARY, JANUARY 1 TO JULY 1, 1893.

Books Purchased:

Transactions of the American Institute of Electrical Engineers. Vol. IX.

Proceedings of the Physical Society of London. Vols. I.-VIII.

Brewster's Journal of Science, complete. By Sir David Brewster.

Brewster's Journal of Science, 2d series, complete. By Sir David Brewster.

Minutes of Proceedings of Institute of Civil Engineers. By James Forrest.

The Edinburgh Philosophical Journal. By Dr. Brewster and Professor Jameson.

The Iron and Steel Institute in America in 1890.

Report of the British Association for the Advancement of Science for 1889.

Report of the British Association for the Advancement of Science for 1890.

Report of the British Association for the Advancement of Science for 1891.

The Theory of Screws. By R. S. Ball.

Pumping Machinery. By William M. Barr.

Senior Course in Mechanical Drawing. By William H. Thorne.

Alternating Currents. By Fred. Bedell.

A Dictionary of Electrical Words. By Edwin J. Houston.

A Practical Treatise on Natural and Artificial Concrete. By Henry Reid.

Engineering Chemistry. By H. J. Phillips.

Commercial Organic Analysis. Vol. III., Part 1. By Alfred H. Allen.

Plant Analysis. By Dr. G. Dragendorf.

Corliss Engines. By W. H. Uhland.

Des Ingenieurs Taschenbuch.

Chemische-technische Untersuchungsmethoden. By Dr. Friedrich Böchmann.

Die Einrichtung Elektrischer Beleuchtungsanalgen. By Dr. Carl Heim.

Kurze Anleitungzur Technisch-Chemischen Analyse. By Dr. Ludwig Medicus.

Die Qualitative und Quantitative Bestimmung des Holzschliffs. By Dr. Albert Müller.

Schmieröluntersuchungen. By A. Martens.

Die Mikroskopische Untersuchung des Papiers. By Dr. Julius Weisner.

Mittheilungen aus dem Mechanisch-Technischen Laboratorium. By J. Bauschinger. Parts 1–22.

Mittheilungen aus den Koniglichen-Technischen Versuchsanstalten zu Berlin. 1892.

Jahresbericht der Chemischen Technologie. 1892. By Dr. Ferdinand Fischer.

Index Chemisches Central-Blatt. 1885, 1886, 1887, 1888, 1889, 1890. By Dr. Rudolph Arendt.

Revue Internationale des Falsifications. By Dr. P. F. Van Hamel Roos.

Specifications and Drawings of Patents. U. S. Patent Office. June, July, August, September, October, November, December, 1891.

Contributed:

By President Morton. *Transactions American Society of Mechanical Engineers.* XIII.

By Professor Anderson. *Slide Vale Gears.* By Hugo Bilgram.

By Edward B. Gallaher. *The Science Record*, 1872.

By Prof. R. H. Thurston. *Essais de Machines et Chaudieres à Vapeur.* By R. H. Thurston.

By Prof. R. H. Thurston. *Traité de la Machine à Vapeur.* By R. H. Thurston.

By Conway McMillin. *The Metaspermae of the Minnesota Valley.* By Conway McMillin.

By Hon. G. B. Fielder. *Eleventh Census of the United States. National Industries.*

By Hon. G. B. Fielder. *Eleventh Census of the United States. Public Debt.*

By Hon. G. B. Fielder. *Eleventh Census of the United States. Population.*

By Hon. G. B. Fielder. *Tenth Annual Report U. S. Geological Survey.*

By A. A. Pope. *A Catalogue of Books, Pamphlets, etc., Relating to the Construction of Roads.* By Col. A. A. Pope.

By Dr. J. A. Coles. *Abraham Coles, A Biographical Sketch.* By John Ackerman Coles.

By Smithsonian Institution. *Smithsonian Report, U. S. National Museum.*

By Smithsonian Institution. *Bibliography of the Athapascan Languages.* By James C. Pilling.

By Smithsonian Institution. *Bureau of Ethnology, Seventh Annual Report.* By J. W. Powell, Director.

By Smithsonian Institution. *Proceedings of the U. S. National Museum.* Vol. XIV.

By Smithsonian Institution. *Annual Report of Regents of the Smithsonian Institution,* 1890.

By Smithsonian Institution. *Notes on the Preparation of Rough Skeletons.* By Fred. A. Lucas.

By Smithsonian Institution. *Directions for Collecting Recent and Fossil Plants.* By F. H. Knowlton.

By Smithsonian Institution. *Directions for Collecting Birds.* By Robert Ridgway.

By Smithsonian Institution. *Directions for Collecting, Preparing, and Preserving Birds' Eggs and Nests.* By Charles Bendire.

By Smithsonian Institution. *Directions for Collecting and Preserving Insects.* By C. V. Riley.

By Smithsonian Institution. *Directions for Collecting Reptiles and Batrachians.* By Leonard Steneger.

By Smithsonian Institution. *Instructions for Collecting Mollusks, Etc.* By William H. Dahl.

By Smithsonian Institution. *Bibliographies of American Naturalists.* No. 4. By L. S. Foster.

By Smithsonian Institution. *On the Application of Interference Method in Spectroscope Measurements.* By Albert A. Michelson.

By Smithsonian Institution. *Patent Centennial Celebration.*

By U. S. Department of Agriculture. *Experiment Station Record.* November, 1892.

By U. S. Department of Agriculture. *Experiment Station Record.* February, 1893.

By U. S. Department of Agriculture. *Report on the Climatology of the Cotton Plant.* By P. H. Mell.

By U. S. Navy Department. *Report of Superintendent of the U. S. Naval Observatory.*

By U. S. War Department. *Annual Report of Chief of Engineers, U. S. Army.*

By U. S. Department of State. *Fire and Building Regulations of Foreign Countries.*

By U. S. Department of State. *Australasian Sheep and Wool.*

By U. S. Department of State. *Reports of Consuls of the United States.*

By U. S. Department of State. *Tariffs of Foreign Countries.*

By U. S. Department of the Interior. *A Dakota-English Dictionary.* By Steven Return Riggs.

By U. S. Treasury Department. *Annual Report of the Lighthouse Board.*

By U. S. Commissioner of Labor. *Labor Laws of Various States.*

By N. J. Agricultural Expert Station. *Fungus Diseases of the Quince Fruit.* By B. L. Halstead.

By Geological Survey of Minnesota. *The Mammals of Minnesota.* By C. L. Herrick.

By Geological Survey of Minnesota. *Bulletin No. 8 of the Geological Survey of Minnesota.* By Andrew C. Lawson.

By Geological Survey of Minnesota. *The Geological and Natural History Survey of Minnesota.* By N. H. Winchell.

By Geological Survey of Minnesota. *Mineral Resources of the United States.* 1891. By David T. Day.

By the Philosophical Society of Washington. *The Moon's Face.* By G. K. Gilbert.

By the University of Chili. *Anales de La Universidad Republica de Chili.*

By the American Society of Mechanical Engineers. *Transactions.* Vol. XIV.

THE STEVENS INDICATOR.

VOL. X. OCTOBER, 1893. NO. 4

EXTRACT FROM LECTURE NOTES, 1893.

PROF. COLEMAN SELLERS.

MECHANICAL INTEGRATOR.

MESSRS. Amsler-Laffon & Sohn, of Switzerland, have written to me in reference to the use of their mechanical integrator when it is desirable to obtain the polar moment of inertia and center of gyration from the vertical cross-section of any circular symmetrical figure in relation to its axis of rotation.

Early this summer, I ordered one of these instruments, without full knowledge of its capabilities, as an addition to my collection of instruments useful to mechanical engineers. My object in ordering the integrator was to use it as an illustration of one of my lectures, after having employed it in some very important work in the study of the flywheel effect of the revolving parts of the dynamos to be driven by the water wheels at Niagara Falls; each water wheel of 5,000 horse-power, in this case, propelling, by means of a vertical shaft, a dynamo of the same capacity. The proper governing of the speed of the water wheels, which revolve at the rate of 250 revolutions per minute, calls for a flywheel effect from all the revolving parts of both the water wheel and the dynamo,

while the weight that may be made to revolve in the dynamo itself is limited to about 80,000 pounds, but so proportioned as, in conjunction with the other revolving parts counterbalanced by water pressure, to yield an effect measured by the weight into the square of the diameter = 1,100,000,000 pounds. The mechanical integrator, if applicable, would not only simplify tedious investigation but check such work as is usually done.

Upon receipt of this instrument, its non-fitness for the required work, at least so far as the directions given by the makers would explain, was apparent; and a rather interesting correspondence began with other users, as to the possibility of finding some ratio between, the moment of inertia as obtained by means of the instrument, predicated upon the sectional form of matter of equal weight in each moment of the area, and the polar moment of a sectional form, say a flywheel rim, which is heavier near the circumference than it is nearer to the center about which it rotates.

The following letter from Switzerland is given in full as instructive. It was accompanied by blue-prints of two transformed sections, all referred to in the letter. This drawing, full size, having located upon it the position of the bar upon which the integrator runs, I have had reduced for publication, and upon the diagram have retained the original calculations inscribed on the blue-prints, in order to afford at a glance an example of the method to be pursued in applying the integrator in such cases.

I shall ask for the publication of this letter in the INDICATOR, as it will make a valuable addition to the book of instructions that accompanies the instrument. Here follows the letter:

"We regret that you did not mention the uses you intended the integrator for before ordering it, otherwise we should have recommended to you a modified integrator giving the polar moment of inertia directly. We made some similar instruments for ballistic investigations.

"The ordinary integrator does not allow of measuring directly the polar moment of inertia, this requiring the measurement of

$\int y^4\,dx$ whilst the integrator measures only the integrals $\int y\,dx$, $\int y^2 dx$, $\int y^3 dx$.

"After having transformed the section of the rim of a flywheel in rather a simple way, it is, however, possible to measure the polar moment of inertia by means of the ordinary integrator.

"This we will explain in the following:

"Let $x\,x$ denote the axis of the flywheel.

V the volume of the flywheel.

I_p the polar moment of inertia of the flywheel.

Then

$$V = \pi \int y^2\,dx$$

$$I_p = \tfrac{\pi}{2} \int y^4\,dx.$$

"The volume might be measured directly on the diagram by the M roller of the integrator, but it is more convenient to measure it on the transformed diagram.

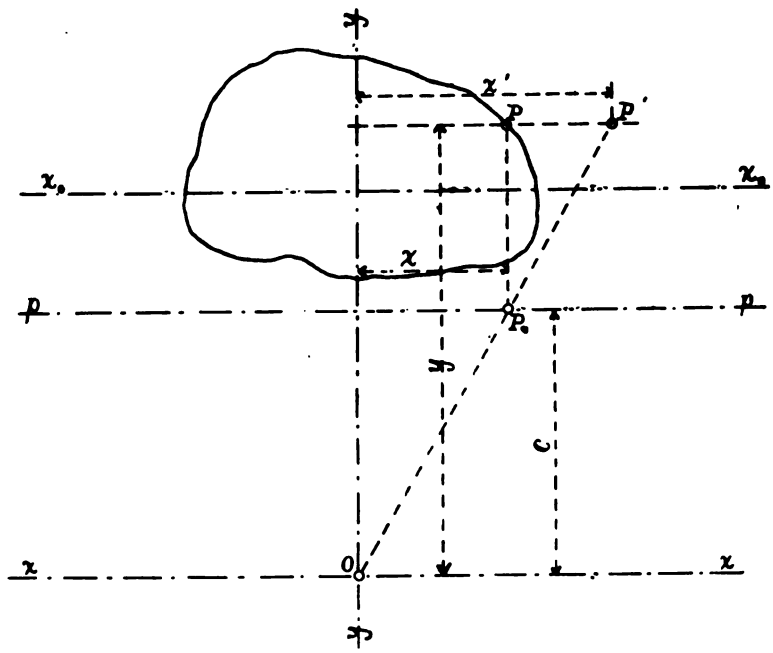


FIG. 1.

TRANSFORMATION OF THE DIAGRAM.

"Draw a straight line P P parallel to $x\ x$ at any distance C. Draw the axis of ordinates $y\ y$ and choose it such that it crosses the diagram near the middle (which, however, is not necessary but convenient). In order to transform any point P of the outline of the diagram, draw a line through P parallel to $x\ x$ and another line parallel to $y\ y$. Then draw a line through O and P_0. The point of intersection P' will then be the transformed point.

"Proceed in the same way for other points of outline of the original diagram and join the transformed points by a continuous line. This will then be the transformed diagram which is to be used for the mechanical integrator.

"Denoting now the area of the transformed diagram by A' and the ordinary moment of inertia of the transformed diagram by I', the axis of moments being $x\ x$, then

Volume of flywheel $V = 2\pi\ r\ A'$,

Polar moment of inertia of flywheel $I_p = 2\ \pi\ r\ I'$,

and radius of gyration

$$\overset{\circ}{\delta} = \sqrt{\frac{I_p}{V}}$$

"If the drawing of the flywheel is very small, it may be possible to follow with the pointer of the integrator the outline of the transformed diagram when the integrator is adjusted to the line $x\,x$ as axis of moments. This would be the simplest case. Usually, however, the distance of the rim of the flywheel from the axis of rotation is so great, at least if the flywheel be drawn full size or on a large scale which should be thus done for accuracy's sake, that it is not possible to measure the diagram when the integrator is adjusted to the axis of rotation. In this case draw an auxiliary axis $x_0\ x_0$ across about the middle of the diagram and parallel to the axis $x\ x$. Let h denote the distance between the lines $x\ x$ and $x_0\ x_0$. Adjust the integrator to $x_0\ x_0$, so that the rail is above the diagram.

"Then measure the area A', the moment M'_0 and the moment of inertia I'_0 of the transformed diagram relatively to the new axis of moments $x_0\, x_0$.

$$\text{Then, } I' = I_0 + h^2\, A' + 2\, h\, M'_0,$$

and, therefore,

$$I_p = 2\, \pi\, c\, (I_0 + h^2\, A' + 2\, h\, M'_0).$$

"In order to make the method quite clear, we send you two specimen calculations of the same flywheel, the rim of which has quite an irregular fancy shape. The two calculations differ only in the choice of the distance c. The results should be the same in both cases. The slight discrepancies result from inaccuracies in the drawing. The work is a good deal simpler than it may appear from the foregoing explanation.

THEORY

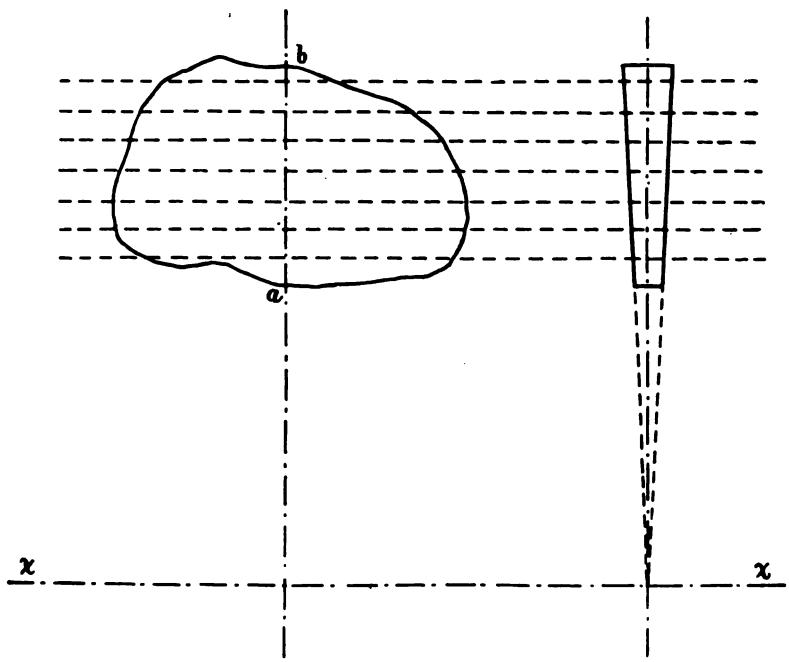


FIG. 2.

"The figure represents a cross-section through the flywheel. The wedge represents an element of the flywheel, inclosed between two consecutive sections of the rim. Suppose now the section to be divided by a set of lines parallel to $x\,x$. The thickness of the wedge increases at a constant rate when going from a to b. Imagine now each portion between two consecutive parallel lines to be stretched sideways at the same rate as the thickness of the corresponding portion of the wedge increases. The new diagram will then be such as to contain in its area also the variable thickness of the wedge. The new diagram allows therefore to operate in the plane as if it were a wedge. Referring to Fig. 1, and denoting the co-ordinates of point P' $v\,y$ $x'\,y$ we see that

$$\frac{x'}{x} = \frac{y}{c} \qquad x' = \frac{x\,y}{c}.$$

"The ordinary moment of inertia of an infinitely small portion of the transformed diagram along the line P', P will be expressed by

$$d\,I' = y^2\,x'\,dy = y\,\frac{3\,x}{c}\,dy,$$

and by integrating over the whole diagram

$$I' = \frac{1}{c}\int y^3\,x\,dy.$$

Considering that $\int y^3\,x\,dy = \iint y^3\,dx\,dy = \frac{1}{4}\int y^4\,dx$

we have $$I' = \frac{1}{4c}\int y^4\,dx$$

Comparing this expression with the formula

$$I_p = \frac{\pi}{g}\int y^4\,dx$$

we get $$I_p = 2\pi c\,I'.$$

"In a similar way we find for the element of area of the transformed diagram the expression

$$d\,A' = x'\,dy = \frac{x\,y}{c}\,dy$$

$$A' = \frac{1}{c}\int x\,y\,dy = \frac{1}{c}\iint y\,dy\,dx = \frac{1}{2c}\int y^2\,dx$$

"Comparing this with the expression for V,

$$V = \pi \int y^2 \, dx,$$

we get $V = 2 \pi c A'$."

The makers have been asked for full particulars as to the character and form of the instrument as made for the ballistic experiments alluded to in the first part of the letter. Upon the receipt of their reply, I propose to explain the scope and convenience of the modified integrator intended to give by a simple reading the polar moment of inertia required.

A TRANSPARENT DEVICE, ILLUSTRATING THE OLDHAM COUPLING.

BY PROFESSOR C. W. MAC CORD.

THE accompanying cut represents a model designed to illustrate the principles and the action of the Oldham coupling, used for connecting two shafts whose axes are parallel, but not coincident. This coupling consists of a thick disk, in the opposite faces of which are planed two deep and wide slots, crossing each other at right angles. A rib of corresponding depth and width is formed across a flange on the end of each shaft, and these ribs slide in the slots on the disk. This construction may be modified in detail, but in any form, it will be readily apprehended that a working model, while it would clearly enough exhibit the resulting rotations of the two shafts in the same direction, and with the same velocity, would be of little use in studying the apparently wabbling movement of the disk; or, in tracing the action of the various parts upon each other, since in such a model all of them could not be seen at once, and since certain points and lines, whose

positions and relative motions form essential parts of the theory, would not be seen at all.

In this model all these things can be seen at the same time, and their relations studied either in motion or at rest. The disk, which represents the coupling, is made of plate glass, and the two slots are formed in its lower face. The ribs upon the flanges of the shafts are represented by two ebony blocks, which turn freely on two pins fixed in the base board ; these pins represent the axes of the shafts, and the blocks, sliding freely in the slots, control the movements of the disk. As a matter of fact, we must of course move the disk around by hand, when the two blocks will be seen to turn, as above stated, in the same direction with equal speeds.

The centre of the disk travels in a circle, whose centre is midway between the two pins; the circumference A, of this circle, which passes through the centres of the pins, is distinctly marked on the surface of the base board, and vertically over its centre there is fixed, in a small bracket supported by a stationary bar extending

across the disk a little above its surface, the central pivot of a small pointer, whose total length is equal to the diameter of the circle A. This pointer is carried round by a small pin at one end, which projects downward into a hole drilled in the centre of the glass disk. By this means it is made perfectly obvious that the centre of the disk will describe this circumference twice, while each of the ebony blocks turns once; in other words, this revolution has twice the angular velocity of that of either shaft.

It is moreover a fact, the demonstration of which by diagrams seems obscure to many, that this motion of the disk is the same as though it were carried by an annular wheel, rolling round the circumference of a fixed one of half its size. This is very clearly illustrated in this device; a circle B, is described around the centre of the disk upon its lower surface, with a radius equal to the distance between the centres of the pins; or, in other words, to the diameter of the circle A. Thus, as the disk goes round, the circumference of the larger circle is seen to measure itself off upon that of the smaller, and the end of the pointer indicates the point of contact. The action, then, may be explained by saying that the disk revolves twice around the intermediate axis, and in the same time rotates once about its own axis in the opposite direction.

The same mechanical combination is applied to another purpose, being in all essential features, and in its mode of action, identical with the "elliptic chuck," and this application also is well shown by this model.

No doubt many who never saw either the chuck or the coupling would at once recognize this disk were it inverted, and the ebony blocks pivoted to a movable bar, as an old acquaintance; knowing that a pencil fixed anywhere on the bar would trace an ellipse on the disk, supposing the latter to remain stationary. In the present instance, the conditions are reversed; but the relative motions of the disk and the bar are precisely the same. This fact is distinctly brought out by means of a pointed pen charged with an

ink capable of marking on the glass; this may at pleasure be slipped into a socket attached to the stationary bar previously mentioned, which is permanently secured to the base board.

In the model as constructed, an abbreviated "stylographic" pen is used; this may be filled with carmine, Prussian blue or India ink, rubbed up in water mixed with glycerine; and thus, as the disk is moved around, the formation of the ellipse, and the relative motions of the parts upon which its formation depends, may be simultaneously studied.

Of course, an ellipse might have been permanently marked on the upper surface of the disk, just as the circle B is upon the lower, in which case a fixed pointer attached to the bar might be used. But the effect is much more striking, as well as more instructive, when the curve is shown in the actual progress of its generation.

A SIMPLE GEOMETRICAL PROOF FOR THE ZEUNER VALVE DIAGRAM.

BY PROF. ROBERT M. ANDERSON.

SOME simple geometrical proofs for the Zeuner valve diagram and its application to the Meyer cut-off gear, occurred to me about two years ago. Since then I have seen the subject illustrated in a somewhat similar manner in "Homes' Steam Engine,"*

* Text-Books of Science; "The Steam Engine," by George C. V. Holmes.

but as his reasoning is not quite so direct, I have concluded to publish the following :

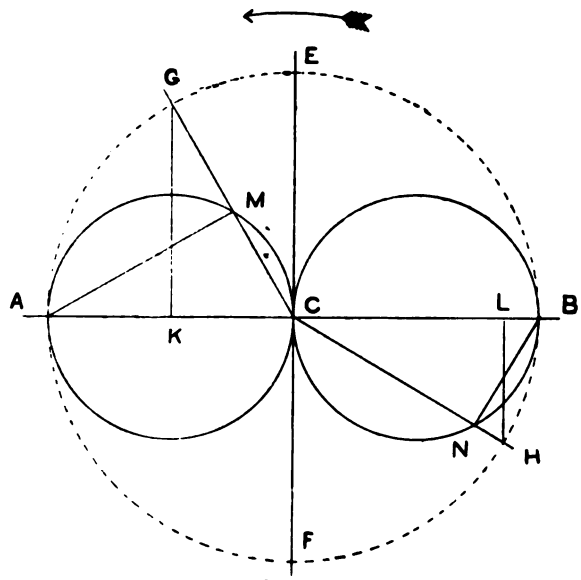


Fig. 1

The dotted circle on the diameter A B, Fig. 1, represents the path of the eccentric's centre around the axis of the engine's shaft; the diameter A B being parallel to the plane of the valve's motion. If the ratio of the length of the eccentric rod to the eccentricity be taken sufficiently great, the movement of the valve may be considered that of a pure harmonic. In the practical use of the Zeuner diagram, the eccentric rod is considered of infinite length, in which case the movement of the valve, from its central position, is equal to the projection of the eccentric line upon the diameter, as, for example, the projection C K of the radius C G upon A B, or the projection C L of the radius C H.

Two similar and equal triangles, A M C and G K C, are formed by drawing from the end A, of the diameter A B, a line perpendicular to the eccentric radius C G. They are similar, because

the angle at C is common to both, the angles at A and G are equal, as the sides are mutually perpendicular, and the angles at K and M are both right angles. A C and G C being equal radii, the triangles are equal, and the side C M is equal to the side C K. But as C K is the movement of the valve from its central position, the side C M must also be equal to that part of the valve travel. The angle at M being a right angle, this point will always be in the circumference of a circle, having A C for a diameter. It follows from this that the chords formed by different eccentric radius positions in two circles, drawn on C A and C B as diameters, will equal the respective distances that the valve has traveled from its middle position. This is illustrated in Fig. 1, where C M is equal to C K and C N to C L.

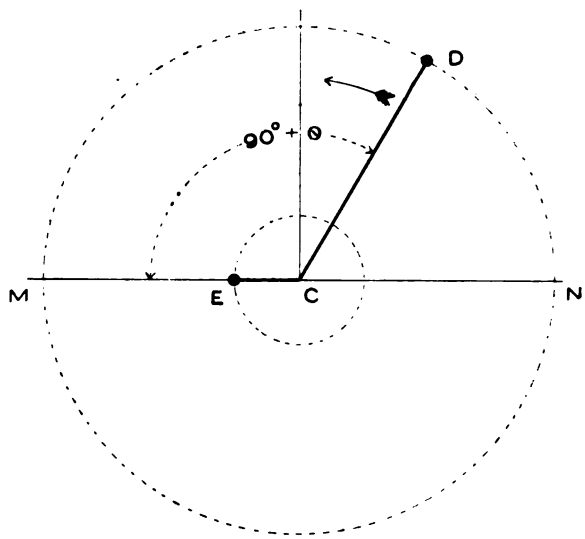


Fig. 2.

The relative position of the crank C D with the eccentric radius C E is shown in Fig. 2, the eccentric line C E being placed 90 degrees plus some angle θ in advance of the crank.

In order not to be required to draw two sets of lines, such as C E and C D at $(90+\theta)$ degrees apart, representing the crank and

eccentric lines, the crank positions may be made to answer for both by revolving the valve diagram of Fig. 1 backwards, through the $(90 + \theta)$ degrees, as is shown in Fig. 3.

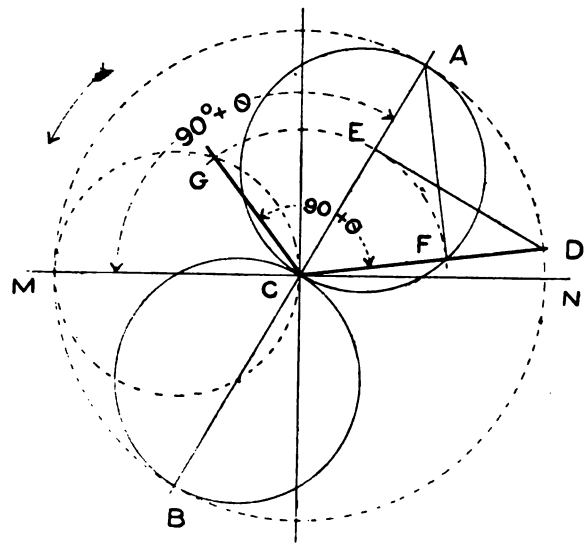


Fig. 3

If the two small circles on B C and C A as diameters (Fig. 3) are the eccentric circles after revolving the diagram backwards, and the small dotted circle M G C, one of these, C F A, in its original position, the chord C G cut by the eccentric radius C G in the circle M G C will be equal to the chord C F, cut by the crank C D in the revolved circle C F A. This is shown in the figure by the arc G E F passing through the points G, E and F, making C G and C F equal to the valve movement C E. The eccentric radius C G is $(90 + \theta)$ degrees in advance of the crank C D. Similarly for the eccentric at M C and the crank at C A, the chord M C equals to the chord C A. Therefore, in the new diagram, the crank positions only are necessary, or the crank and eccentric may be considered to coincide, as the chord G C becomes the chord C F.

Hence such crank positions as C N, C D, C H, C M, etc., will now form in the circles having the diameters A C and C B, chords which equal the corresponding travel of the valve from its central position. This constitutes the ordinary Zeuner diagram.

The Zeuner Diagram for the Meyer Cut-off Valve.

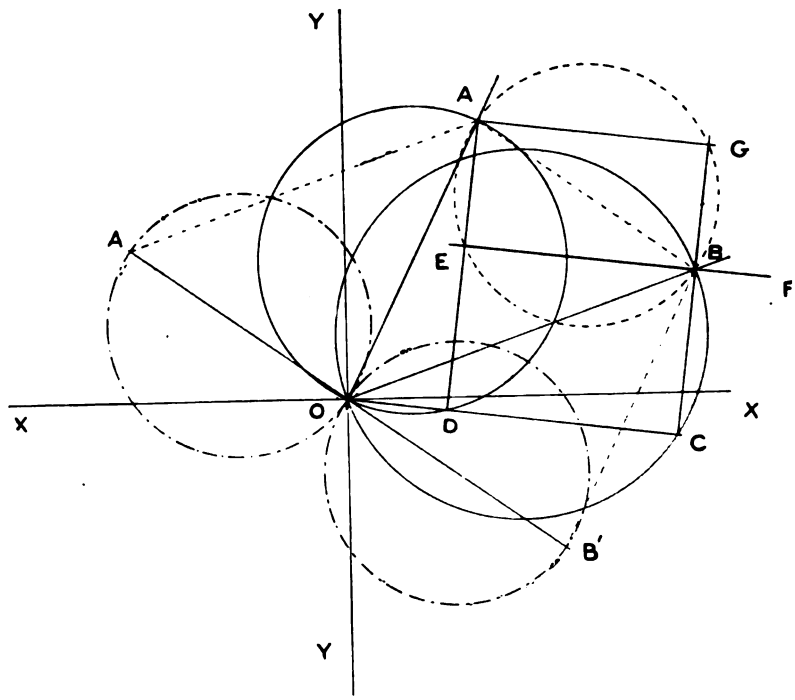


Fig. 4.

The circle on the diameter O A, Fig. 4, is the half travel circle of the main valve, and the circle on O B is the same for the expansion or cut-off valve. For any crank position such as O C, the chord O D in the circle O D A gives the travel of the main valve from its central position, and the chord O C in the circle O C B gives the travel from its middle position of the expansion valve.

Hence the centres of the two valves have moved apart at that instant a distance D C equal to the difference of their chords.

In the main valve circle O D A, draw a line from A to D. The angle formed at D with the line O D C is a right angle, being measured by the semi-circumference on the diameter O A. In the expansion valve circle draw a line from B to C. The angle at C is also a right angle for a similar reason. The lines A D and B C, being perpendicular to the same line, are parallel. If the line E B F be drawn through B parallel to the crank position O C, it will form a rectangle with the lines H E D, O D C, and B C, whence the distance E B will equal the distance D C between the centres of the main and expansion valves. As the angle B E A is a right angle, the point of intersection E will always be in the circumference of a circle having A B for a diameter, A B being the line joining the ends of the diameters of the main and expansion valve circles.

The same proof applies if the line be drawn through A parallel to the crank position, and intersecting the line B C continued as at G.

From this it follows that if from either end of the diameter A B of the dotted circle A E B, lines be drawn parallel to the crank positions, the chords so formed will be equal to the distances between the centres of the two valves. The crank lines themselves may be used to form the cords if we move the auxiliary valve circle parallel to its diameter A B into the two positions A′ O and O B′, having one end of the diameter coinciding with the point O. The relative positions of the two valves will now be equal to the chords in the two broken line circles A′ O and O B′ formed by the different crank positions.

DETERMINATION OF THE WATER CONSUMPTION OF A BALL & WOOD ENGINE WHEN RUNNING UNDER LIGHT LOADS.

BY HERBERT B. COOK, '93, AND ALFRED B. LORD, '93.

THE engine employed in making this determination was sent to Stevens Institute by the manufacturers April 10, 1893, and was at once set up in the basement of the building.

It was a 50 horse-power standard single-cylinder engine of the following dimensions:

Diameter of cylinder	10 inches.
Stroke	11 "
Diameter of piston rod	1½ "
Diameter of crank pin	4½ "
Diameter of governor wheel	5 feet
" " flywheel	5 "
Length of connecting rod	33 inches.
" " eccentric rod	37½ "

As a cheap temporary foundation was all that was requisite for a test of the nature of the one contemplated, two pieces of 12x12-inch timbers about 8 feet long were imbedded in the earth through a brick floor, and the iron base of the engine nearly 2 feet high was securely bolted to them. The bricks were relaid about the timbers and cemented firmly together.

After having properly set up the steam and exhaust pipes, a Wheeler surface condenser, capable of condensing 1,500 pounds of steam per hour, was suspended from the beams of the floor over-

head and connected to a tee in the exhaust pipe. A 2-inch pipe was used to circulate the condensing water, the water entering the condenser at the bottom and leaving from the top. The steam condensed was led from the condenser into two barrels, the pipes being so arranged that as soon as one barrel was filled the condensed steam was turned immediately into the other barrel.

The exhaust outlet was 4 inches in diameter, and accordingly a 4-inch pipe was used to carry away the exhaust steam. Since the outlet at the drum of the boiler was only 2½ inches and the throttle valve was designed for a 3½-inch pipe, the following device was resorted to, the object being to obtain a uniform flow of steam into the steam chest. A 2½-inch pipe about 30 feet long was led directly to a point above the throttle valve, and a 6-inch chamber about 5 feet long connected this to the throttle valve, thus forming a reservoir for storing steam.

The power was absorbed by a brake made especially for the purpose. It consisted of a rope 2 inches in diameter and 18 feet long, hung in a frame resting upon platform scales in such a manner that the difference of tension was measured directly on the scales, a wheel with a lock-nut attached being used to adjust the tension.

In order to keep the flywheel cool and prevent it from expanding by the friction of the brake, a half-inch pipe was led to the rim of the wheel, and the supply of water regulated by a convenient valve.

For the indicator rigging, half-inch brass pipe was used, connected by two union joints to a three-way cock, to which the indicator was attached. The reducing motion was furnished by the Ball & Wood Co., and consisted simply of two upright pieces of steel, connected by a movable arm, one upright being screwed into the crosshead and the other into one of the guides.

A revolution counter was attached to a screw in the end of the main shaft.

METHOD OF CONDUCTING TESTS.

Each test was of one hour's duration. The engine was allowed to run for ten or fifteen minutes before beginning a test, with the cylinder cocks open, and also the drain valve in the exhaust pipe. All the drain valves were then shut off, and the brake set to produce the required horse-power. Cards were taken every ten minutes, and at the same time the pressure, revolutions, and temperature of the calorimeter were observed.

At the end of each test the condensed steam was accurately weighed.

Two series of tests were made, series A with the pipes uncovered, and series B with them covered with felt 1 inch thick, a calorimeter of the Barrus type being adjusted to the throttle valve to observe the quality of steam.

A summary of the tests is given in Tables I. and II., and the final results are indicated graphically by the curves shown in Fig. 1.

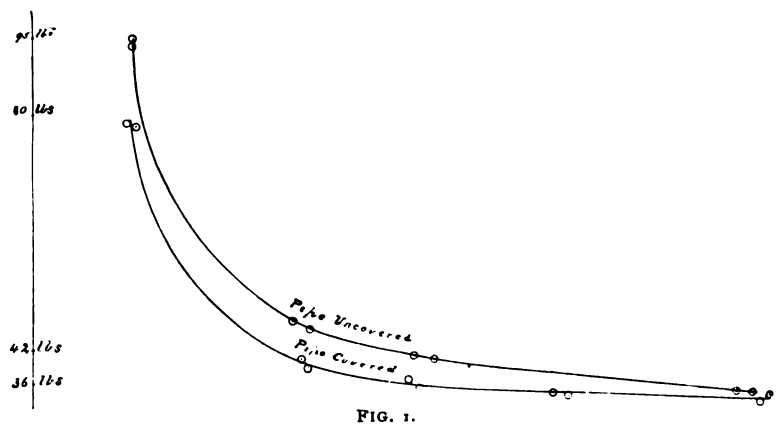
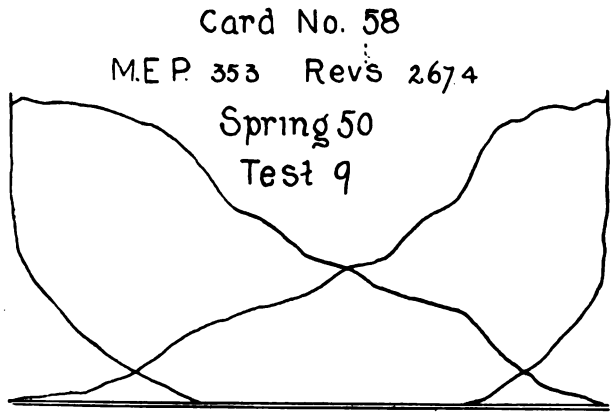
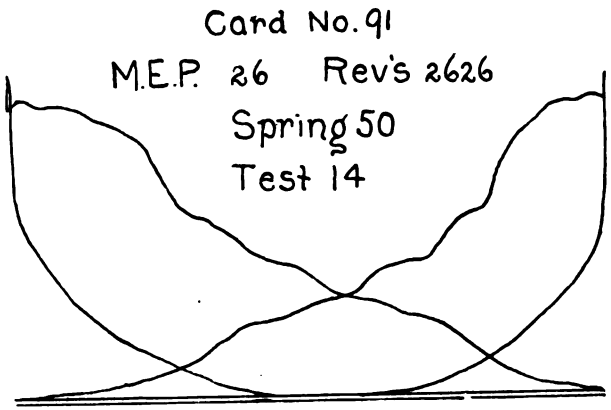


FIG. 1.

Eighteen tests were made in all. The results of nine of these tests are given in detail in Tables III. to XII. The duplicate tests were not made in direct sequence, but other tests were introduced between the times of making duplicate tests. Specimens of the indicator diagrams obtained are shown herewith :


Card No. 58
M.E.P. 353 Rev's 2674
Spring 50
Test 9


Card No. 91
M.E.P. 26 Rev's 2626
Spring 50
Test 14

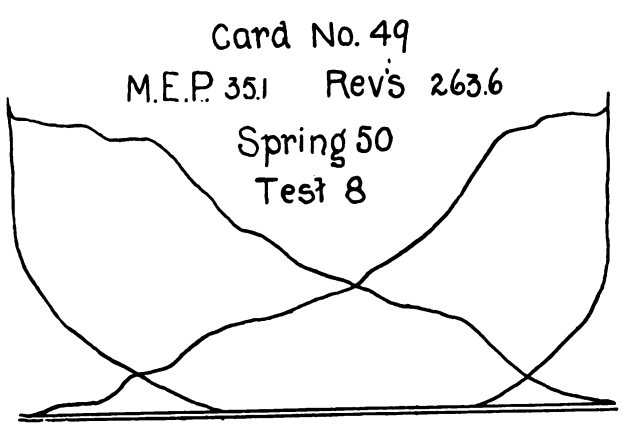

Card No. 49
M.E.P. 351 Rev's 263.6
Spring 50
Test 8

FIG 2.

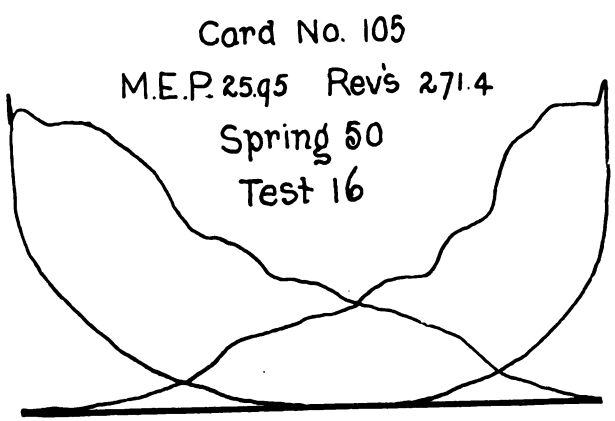
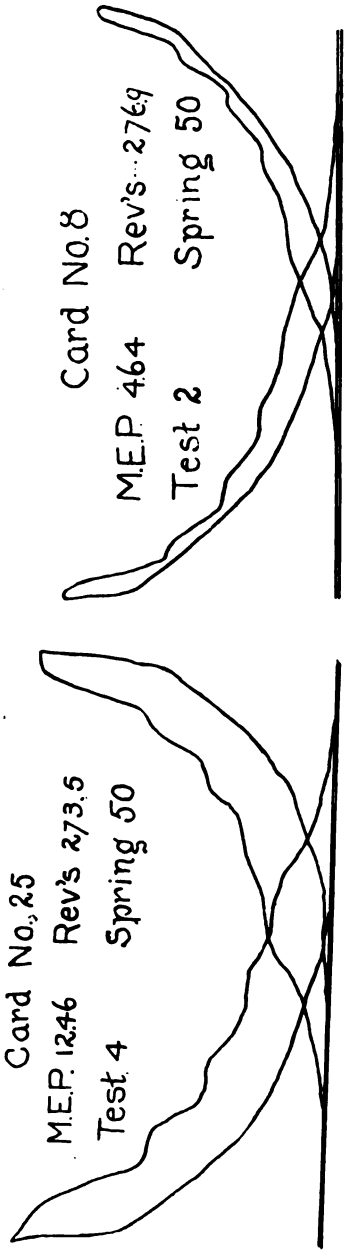

Card No. 105
M.E.P. 259.5 Rev's 271.4
Spring 50
Test 16

FIG. 3.


Card No. 25
M.E.P. 12.46 Rev's 273.5
Test 4 Spring 50

Card No. 40
M.E.P. 12.82 Rev's 283.3
Test 6 Spring 50

FIG. 4.

Card No. 8
M.E.P. 4.64 Rev's 276.9
Test 2 Spring 50

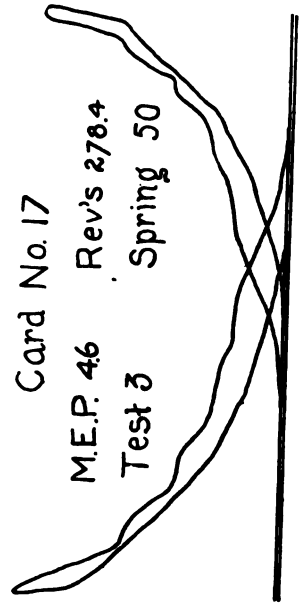

Card No. 17
M.E.P. 4.6 Rev's 278.4
Test 3 Spring 50

FIG. 5.

TABLE II.—*Summary of Tests.*
SERIES A.

Test No.	Average Boiler Pressure.	Average Revolutions.	Average Temp. of Calorimeter.	Mean Effective Pressure.	Indicated Horse-Power.	Brake Horse-Power.	Water Consumed by Engine During Test, Lbs.	Water per Indicated Horse-Power per Hour, Lbs.
2	76.4	276.9	212	4.64	5 54	0	528	95.3
3	81.3	278.4	213	4.6	5.52	0	520	94.2
4	84.6	273.5	213	12.46	14.7	10.09	701	47.68
6	81.7	283.3	212	12.82	15.67	10.45	726	46.33
1	78	279.5	213	17.9	21.58	16.49	906	41.98
5	84.4	280.7	212	18.7	22.64	16.56	932	41.16
8	83.1	262.6	212	35.1	39.77	33.19	1422.5	35.76
9	79.8	267.4	212	35.3	40.72	33.8	1446.5	35.52

TABLE II.—*Summary of Tests.*
SERIES B.

Test No.	Average Boiler Pressure.	Average Revolutions.	Average Temp. of Calorimeter.	Mean Effective Pressure.	Indicated Horse-Power.	Brake Horse-Power.	Water Consumed by Engine During Test, Lbs.	Water per Indicated Horse Power per Hour, Lbs.
13	83.6	285.1	215	4.7	5.78	0	468	80.97
20	87.1	283.4	216	4.42	5.4	0	442	81.85
15	84.3	276.3	214	12.97	15.46	10.19	613	39.65
18	84.8	277.4	219	12.75	15.26	10.23	624	40.89
17	84	279.7	214	18.1	21.84	16.5	798	36.54
19	84.8	274	215	18	21.28	16.17	811	38.11
14	81.8	262.6	214	26	29.4	24.54	1046	35.57
16	82.3	271.4	214	25.95	30.37	25 36	1069	35.2
10	81	272.3	215	35.46	41.65	34.42	1437.5	34.7
11	79	270.1	214	35.36	41.19	34.17	1407.5	34.17

TABLE III.—*Test No. 1.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No. 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight.	Initial. Weight.	Final. Weight.
									Lbs.	Lbs.	Lbs.	Lbs.
P. M.												
9.10	33,959	77	213	1	45	165	120	9.10	70.5	....	....	....
9.20	36,720	77	213	2	45	165	120	9.36	....	478	96	....
9.30	39,546	80	213	3	45	165	120	10.00	70.5	....	....	445
9.40	42,356	80	213	4	45	165	120	10.10	....	220	....	....
9.50	45,175	80	213	5	45	165	120	...	...	...	....	....
10.00	*47,950*	*76*	*213*	..	45	165	120	...	....	....	....	....
10.10	*50,729*	*76*	*213*	..	45	165	120	....	....	...	....	....

TABLE IV.—*Test No. 3.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds. Initial.	Balance.	Net.	Time.	Barrel No. 1. Initial Weight. Lbs.	Final Weight. Lbs.	Barrel No. 2. Initial Weight. Lbs.	Final Weight. Lbs.
11.10	72,433	72	213	13	0	0	0	11.10	75	....	....	....
11.20	75,272	90	213	14	0	0	0	11.56	...	483	95	....
11.30	78,073	87	213	15	0	0	0	12.10	....	....	....	207
11.40	80,863	83	213	16	0	0	0	....	....	...	...	....
11.50	83,659	82	213	17	0	0	0	...	....	....	....	...
12.00	86,393	77	213	18	0	0	0	....	...	....	....	....
12.10	89,137	78	213	19	0	0	0	....	...	...	...	....

TABLE V.—*Test No. 6.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds. Initial.	Balance.	Net.	Time.	Barrel No. 1. Initial Weight. Lbs.	Final Weight. Lbs.	Barrel No. 2. Initial Weight. Lbs.	Final Weight. Lbs.
P. M.												
2.55	39,061	70	212	34	45	120	75	2.55	73	...	....	..
3.05	41,886	77	212	35	45	120	75	3.29	....	495	94	....
....	.....	..	...	..	..	...	..	30	..	....	....	....
3.15	44,744	90	212	36	45	120	75	3.55	..	....	....	398
3.25	47,585	84	212	37	45	120	75	....	....	....	....	...
3.35	50,400	85	212	38	45	120	75	....	....	....	....	....
3.45	53,244	82	212	39	45	120	75	....	....	....	....	....
3.55	56,058	84	212	40	45	120	75	....	....	....	....	....

TABLE VI.—*Test No. 8.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds. Initial.	Balance.	Net.	Time.	Barrel No. 1. Initial Weight. Lbs.	Final Weight. Lbs	Barrel No. 2. Initial Weight. Lbs.	Final Weight. Lbs.
P. M.												
8.17	36,161	77	212	48	45	302	257	8.17	73	...	....	....
8.27	38,774	84	212	49	45	302	257	8.34	....	492	100	....
8.37	41,387	85	212	50	45	302	257	8.49	73.5	...	....	441
8.47	44,026	84	212	51	45	302	257	9.04	....	432.5	100	....
8.57	46,649	84	212	52	45	302	257	9.13	73.5	...	...	320
....	.....	..	...	..	..	...	...	30	....	..	....	...
9.07	49,283	85	212	53	45	302	257	9.17	....	....	...	...
9.17	51,921	83	212	54	45	302	257	....	....	157	....	....

TABLE VII.—*Test No. 13.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No. 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight.	Initial Weight.	Final Weight.
									Lbs.	Lbs.	Lbs.	Lbs.
P. M.												
2.21	17,431	87	216	83	0	0	0	2.21	74	....	...	....
2.31	20,272	84	214	84	0	0	0	3:13	....	480	100	....
2.41	23,148	83	214	85	0	0	0	3.21	....	....	....	162
2.51	26,021	83	214	86	0	0	0	....	...	....	....	....
3.01	28,855	82	215	87	0	0	0	....	....	....	....	...
3.11	31,705	85	214	88	0	0	0	....	....	....	...	....
3.21	34,539	81	214	89	0	0	0	....	....	...	....	...

TABLE VIII.—*Test No. 15.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No. 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight	Initial Weight.	Final Weight.
									Lbs.	Lbs.	Lbs	Lbs.
11.31	61,108	85	214	97	45	120	75	11.31	74	....	....	....
11.41	63,347	84	214	98	45	120	75	12.11	....	481	100	....
11.51	66,581	80	214	99	45	120	75	12.31	....	....	....	306
12.01	69,388	87	214	100	45	120	75	....	....	....	....	...
12.11	72,118	85	214	101	45	120	75	....	....	....	....	....
12.21	74,947	89	214	102	45	120	75	....	....	....	....	....
12.31	77,687	80	214	103	45	120	75	....	....	....	....	....

TABLE IX.—*Test No. 14.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight.	Initial Weight.	Final Weight.
									Lbs.	Lbs.	Lbs.	Lbs.
A. M.												
10.23	43,169	83	216	90	45	235	190	10.23	74	....	....	....
10.33	45,824	83	216	91	45	235	190	10.46	.. .	485	100	....
10.43	48,442	80	214	92	45	235	190	11.04	74	....	....	415
10.53	51,088	88	214	93	45	235	190	11.23	...	394	....	....
11.03	53,699	82	214	94	45	2 35	190	...	....	....	....	...
11.13	56,320	81	214	95	45	235	190	....	....	....	....	....
11.23	58,929	81	214	96	45	235	190	....	....	..	....	....

TABLE X.—*Test No. 10.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No. 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight.	Initial Weight	Final Weight.
									Lbs.	Lbs.	Lbs.	Lbs.
P. M.												
12.19	35,453	83	215	62	45	302	257	12.19	74	....	....	....
12.29	38,195	81	214	63	45	302	257	12.36	...	491	100	....
12.39	40,917	83	215	64	45	302	257	12.50	74	...	....	431
12.49	43,636	81	215	65	45	302	257	1.07	....	474	100	..
12.59	46,358	82	214	66	45	302	257	1.16	75	....	....	294.5
1.09	49,081	82	214	67	45	302	257	1.19	....	170	....	....
1.19	51,794	75	215	68	45	302	257	....	...	....	....	....

TABLE XI.—*Test No. 17.*

Time.	Reading of Revolution Counter.	Pressure, Pounds above Atmosphere.	Temperature of Calorimeter, Degrees Fahr.	Card Number.	Brake Load. Pounds.			Time.	Barrel No. 1.		Barrel No. 2.	
					Initial.	Balance.	Net.		Initial Weight.	Final Weight.	Initial Weight.	Final Weight.
									Lbs.	Lbs.	Lbs.	Lbs.
11.42	34,227	84	216	111	45	165	120	11.42	74.5	....	...	....
11.52	37,069	87	214	112	45	165	120	12.12	....	475.5	100	...
12.02	39,841	85	214	113	45	165	120	12.34	74.5	....	..	370
12.12	42,684	85	214	114	45	165	120	12.42	...	201.5	....	....
12.22	45,435	83	214	115	45	165	120	....	. .	....	...	....
12.32	48,224	85	214	116	45	165	120	....	...	...	....	....
12.42	51,024	80	214	117	45	165	120	....	....	....	....	....

THE CHEMICAL AND PHYSICAL EXAMINATION OF PORTLAND CEMENT.

BY PROF. THOMAS B. STILLMAN, PH. D.

(Continued from page 181.)

NO standard specifications for the testing of Portland cement are required in Great Britain; the determination of fineness and tensile strength being considered sufficient to determine the value of a cement. The machines for tensile strength are the

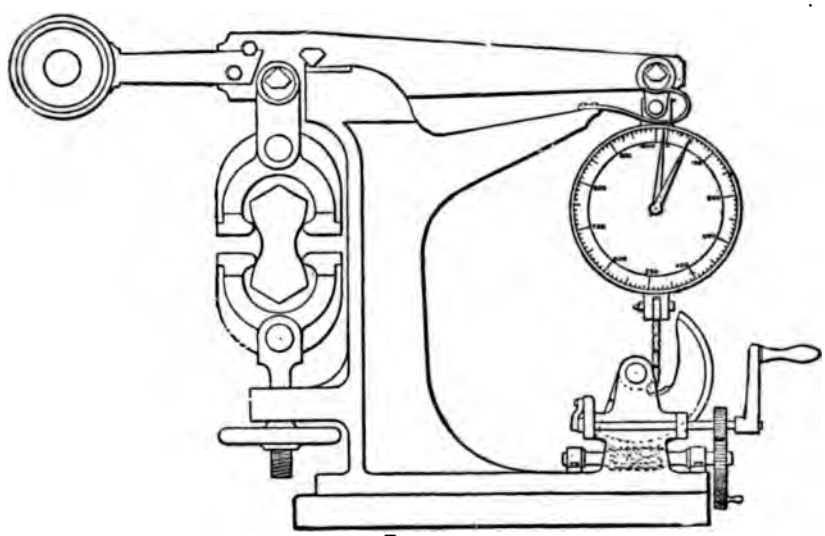


FIG. 5.

"Faija" (Fig. 5); the "Reid and Bailey" (Figs. 6 and 6*a*), or the "Grant," the latter described in *Proceedings* of the Institution of Civil Engineers, Vol. LXII., p. 113. The "Reid and Bailey" is essentially the "Michaelis" (Fig. 4), excepting that water is used instead of fine shot for the breaking power.

It is readily seen that the "Faija" and "Grant" machines, not being automatic, require the application of the power at a certain uniform speed to obtain comparable results, since a difference of 25 per cent. in tensile strength may be obtained by applying the

FIG. 6.

FIG. 6a.

strain very quickly or very slowly (*Proceedings* of the Institution of Civil Engineers, Vol. LXXV., pp. 225, 226).

Faija has determined this variation with extreme care, the result being indicated in the curve shown in Fig. 7. To overcome these variations a uniform speed of 400 pounds per minute has been accepted as the standard.

Not only are comparable methods required in the use of the machines to obtain uniform results, but the briquettes must also be constructed under similar conditions.

It is manifestly unjust to compare the tensile strength of two cements (even when the briquettes are broken upon the same machine) unless the briquettes have the same weight of water for mixing; the same pressure with the trowel when being formed in the molds, and the same length of time exposure under water before submitting the briquettes to the tensile strain. Usually the greatest difference is due to the pressure exerted in forming the briquettes.

For instance: Comparing tests made upon the Dyckerhoff Portland cement by Dr. Böhme, Director of the Royal Commission for Testing Building Materials, at Berlin, and by E. J. De Smedt, General Inspector Engineer Department, District of Columbia, we find that the German method gives a much higher tensile strength than the method in use in this country.

Dr. Böhme.

Age of Briquettes.	Average Tensile Strength per Square Inch.	Number of Tests.
7 days.	767 pounds.	10
28 days.	895 pounds.	10

E. J. De Smedt, C. E.

Age of Briquettes.	Average Tensile Strength per Square Inch.
5 days.	250 pounds.
30 days.	700 pounds.

Showing:

109 pounds increase per day (7 days), Dr. Böhme,
50 " " " " (5 days), De Smedt,

or over 100 per cent. difference upon the same cement.

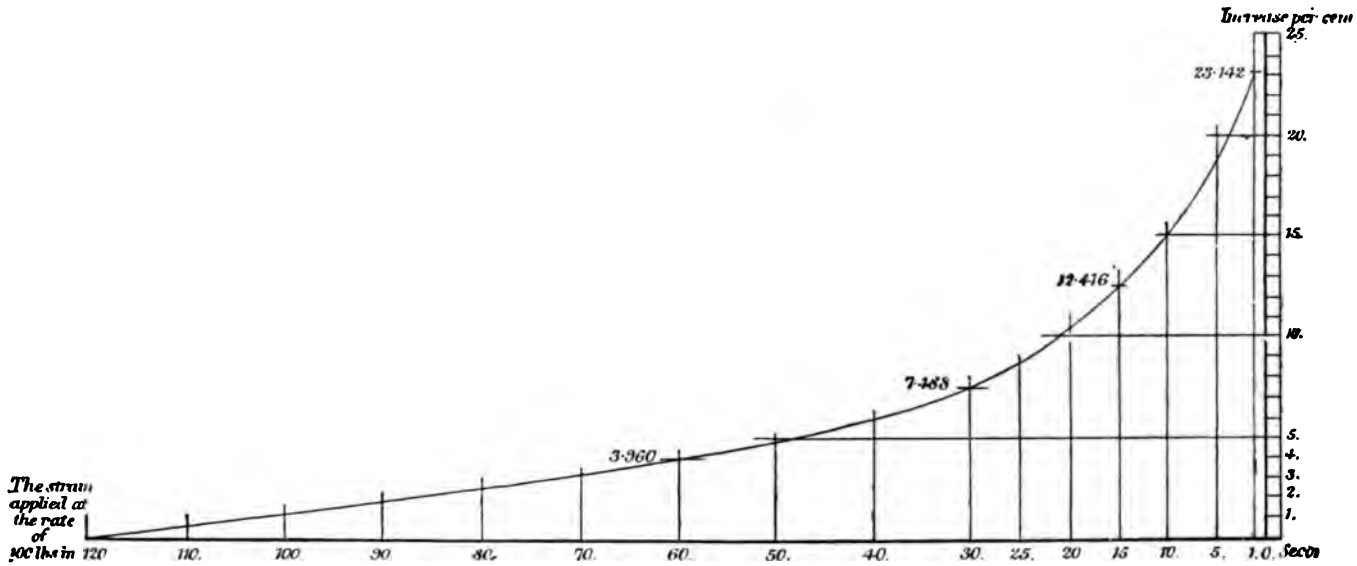

Increase per cent
25.
20.
15.
10.
5.
4.
3.
2.
1.
23·142
12·416
7·488
3·960
The strain applied at the rate of 100 lbs in
120
110.
100.
90.
80.
70.
60.
50.
40.
30.
25.
20
15
10.
5.
1.0.
Secon

FIG. 7.

These variations are undoubtedly due principally to the different pressures upon the cement during the making of the briquettes, and to overcome difficulties of this nature the Vereins deutsche Portland-Cement Fabrikanten have modified the rules in the construction of the briquettes so that two methods are acceptable:

First. The normal method, above given, with the trowel, etc., ("Handarbeit").

Second. The use of the Böhme-Hammer apparatus or "machine method," by which the cement in the briquette form (after mixing with proper amount of water), is submitted to a pressure of 150 blows from a hammer weighing 2 kilos (Fig. 8). The briquette of cement is then removed from the mold and treated for tensile strength as usual.

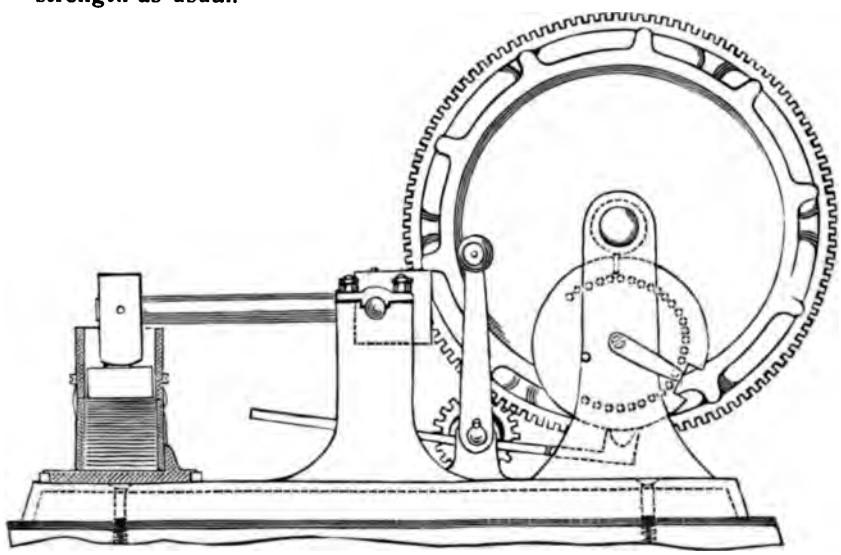


FIG 8.

This subject is receiving considerable attention, at the present moment, the evident purpose being to render the tests of tensile strength as uniform as possible by making the working of the apparatus automatic and the production of cement briquettes with the least possible variation in the pressure in the molds.

In this case, no matter how careful the experimenter may be, the "personal equation" enters largely into the results of testing hand-made briquettes, for which reason the manufacture of the

briquettes should be automatic as possible. In no other way can results obtained by different experimenters be compared.

Prof. Charles D. Jameson describes an apparatus for this purpose (Fig. 9). *Transactions* of the American Society of Civil Engineers, Vol. XXV., p. 302.

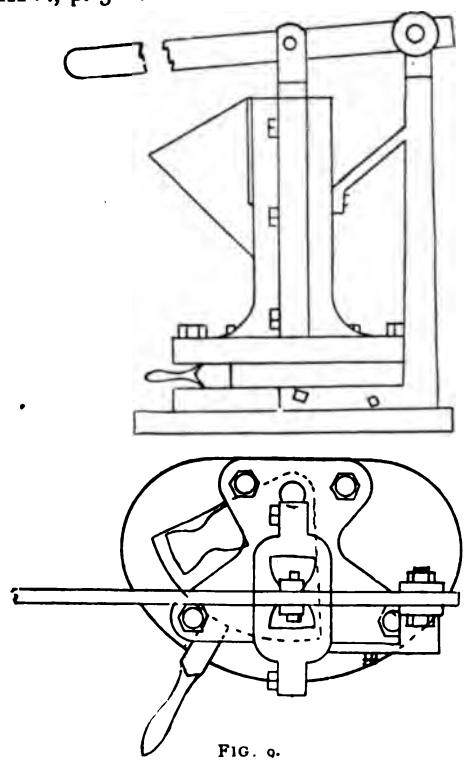


FIG. 9.

The method of operating is as follows: The lever being raised so that the lower end of the piston or main plunger is above the hole in the side of the cylinder communicating with the hopper, cement is put in the hopper and pushed down into the cylinder. The molding plate is pushed against one of the stops, so that one of the openings is beneath the bore of the cylinder. The long lever is forced down, causing the plunger to force the cement into e opening in the molding plate. After this, the molding plate swung against the other stop, cutting off the briquette, placing it er the plungers, throwing the other opening in the molding plate

directly beneath the cylinder. The smaller lever is lifted, raising the plunger, and forces the briquette out of the mold, after which it is removed. The plunger is then pressed down, the main lever also, the molding plate swung back to the first position, the other plunger lever lifted, and another briquette is ready to be taken away, and so on. After making three briquettes, the main lever is lifted and more cement placed in the cylinder. The machine is best operated by two men, one to feed and operate the long lever, and the other to swing the molding plate, remove the briquettes, and lower the plungers. The pressure on the briquette is 175 pounds per square inch.

The conditions required in France for a good cement are: *

First. Analysis to determine the chemical composition.

Second. The determination of density.

Third. The determination of fineness.

Fourth. The determination of tensile strength.

Fifth. The determination of crushing strength.

Sixth. The determination of variation in volume.

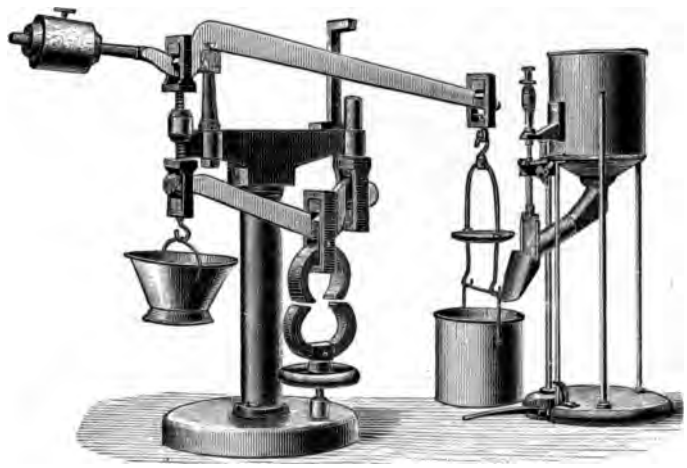


FIG. 10.

The tensile strength is determined by the use of a Michaelis machine, Fig. 10, or the use of a Buignet apparatus, Fig. 11, this latter being upon an entirely different principle than any yet in use,

* E. Candlot, *Ciments et Chaux Hydrauliques*, Paris, Baudry & Co. 1891.

and is thus described by the designer, M. Buignet, Conductor des ponts et chaussées au Havre:

It is composed of a base A and frame B.

The basin A, filled with mercury and water, closes up by a diaphragm of rubber covered with a metallic disk, and is in direct communication with:

(*a*) Manometrique tube D.

(*b*) With a movable reservoir R, filled with mercury, by means of a rubber tube T.

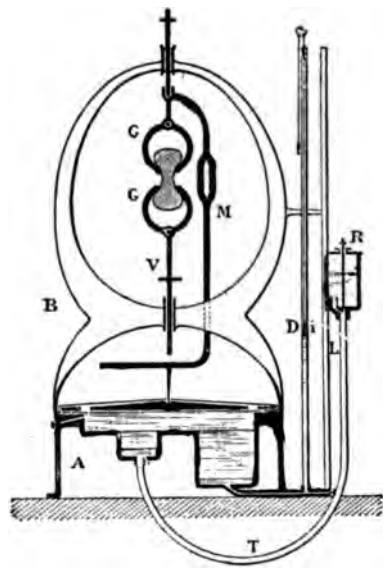


FIG. 11.

The grips G G, in which are to be placed the briquettes to be tested, are fastened, one to the frame B by the support V, the other to the support M, which rests upon the center of the metallic disk over A. It is operated as follows: The briquettes are placed in the grips G G, and the support V moved up or down until equipoise is established, and then firmly secured by a crank in frame B.

The support M is adjusted until the point at its lower end just touches the metallic disk in A.

By gradually lowering the reservoir R an upward pressure is given to the metallic disk in A, which is transferred to the support

M, until when sufficient pressure is exerted the briquette is broken. The moment rupture takes place, of the briquette, the pressure required to do this is indicated by the float I in the manometer tube D.

Another instrument made use of to determine tensile strength, and used at l' ecole des ponts et chaussées, Paris, is shown in Fig. 12.

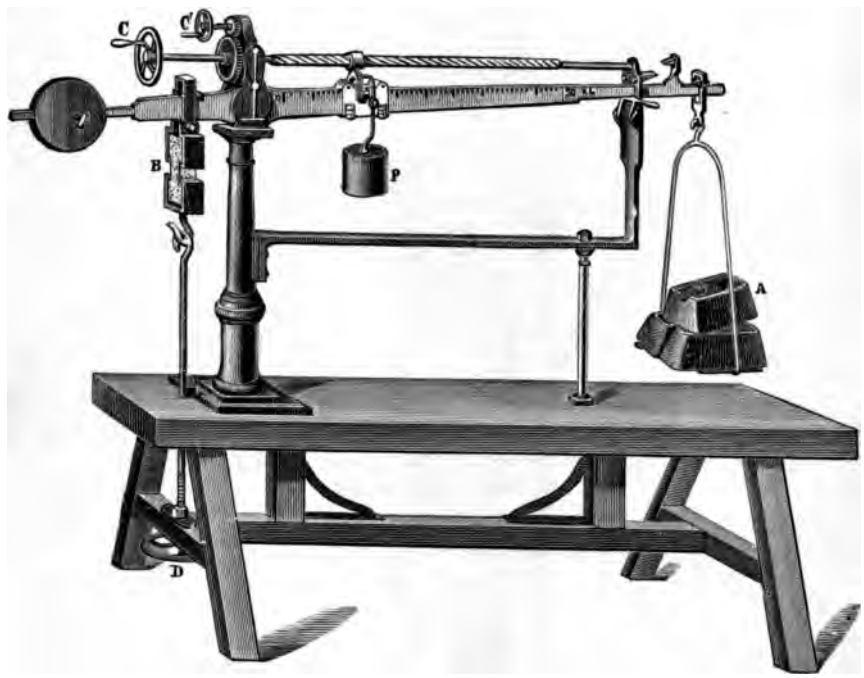


FIG. 12.

It is similar in principle to the Riehle machine (Fig. 2), and the Grant machine (*Proceedings* of the Institution of Civil Engineers, Vol. LXII., p. 98).

By a comparison of the various machines used in Germany, England, France, and the United States, we find practically but two in general use. The "Michaelis" (Figs. 4, 10, and 1), and the "Grant". (Figs. 2 and 12). While nearly all engineers require cements to be subjected to the tensile-strength test, in fact relying more upon this one test than any of the others, it might be well to

include here the opinion of H. Le Chatelier, Professor at the École des Mines, Paris, France, as given in a paper presented at the last meeting of the American Institute of Mining Engineers, August, 1893, entitled "Tests of Hydraulic Materials," p. 44.

FIG. 14.

"The method of tension is at present most widely used, but the preference for it is not well founded.

"Here, as in rupture by bending, only the *surface* of the briquettes acts in a really useful way, and its inevitable irregularities

and alterations so greatly affect the precision of the results that they can in no case be trusted nearer than about 20 per cent.

"This preponderant influence of the superficial parts was first shown by the fact that the resistance of briquettes of different sizes increases, not with the section, but, on the contrary, with the perimeter. Finally, M. Durand-Claye has shown that the interior of a briquette may be removed without notably diminishing its resistance to rupture by tension, and has given a complete theoretical explanation of the phenomena which seemed at first sight paradoxical."

THE CRUSHING TEST.

This test is not official in this country and is seldom required by our engineers, who, however, have confined their experiments in this direction mainly to crushing tests of concrete, formed by mixing Portland cement, sand, and broken stone.

Tests upon cubes of neat cement and of mortar composed of one part cement and three of standard sand, are generally included in reports given upon the examination of cements in Europe; the ratio being that the crushing strength is about ten times greater than the tensile strength.

Thus, a cement of good quality should show the following resistances per square centimeter:

Tensile Strength.

	7 Days	28 Days.
Neat cement.....	25 Kilos	35 Kilos
1 part cement } 3 parts sand }	10 Kilos	18 Kilos

Crushing Strength

	7 Days.	28 Days.
Neat cement.....	250 Kilos	350 Kilos
1 part cement } 3 parts sand }	100 Kilos	180 Kilos

To convert kilos per square centimeter to pounds per square inch, the equivalents used are: 1 kilo = 2.204 pounds English; 6.451 square centimeters = 1 square nch English.

The hydraulic presses made use of for this purpose, a few years since, gave very discordant results, as it was impossible to distribute the pressure evenly over the surface of the cubes. This has been overcome, and there are now four machines upon the market whose results are comparable—viz.:

The "Suchier," Fig. 14; the "Böhme," Fig. 15; the "Tetmajer," as improved by Prof. Amsler-Laffon,* and the "Brink & Hubner."†

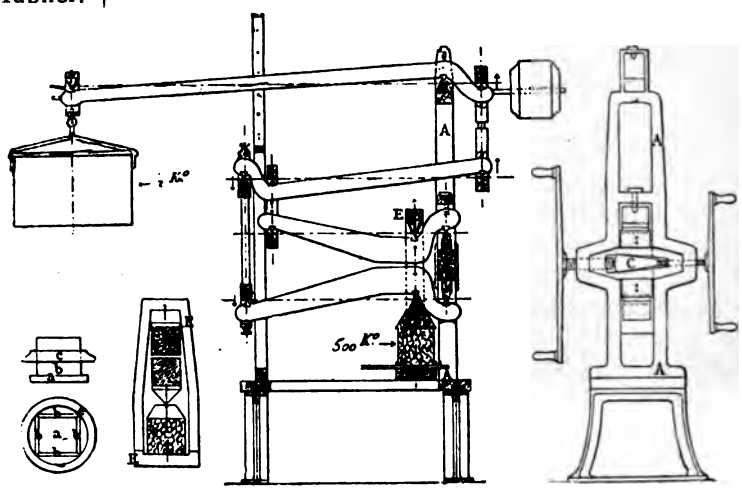


FIG. 15.

Résumé :

The determination of the value of Portland cement requires the following tests:

First. Chemical analysis.

Second. Determination of fineness.

Third. Determination of tensile strength, including the use of automatic briquette machines as well as an apparatus for mixing the cement with water, as "Faija" mixing machine.

Fourth. Determination of crushing strength.

Fifth. Determination of variation of volume.

(TO BE CONTINUED.)

* Consult: *Schweizer Bauzeit*, Jan. 12, 1889.

† Description of the "Suchier," "Böhme," and "Brink & Hubner" machines will be found in *Der Portland-Cement und seine Anwendungen im Bauwesen*, Berlin, 1892.

REFERENCES (1870 to 1892). V

1870.

American Chemist.—Chemical examination of a piece of cement metamorphosed while immersed in the water of Bayen de Luchon, p. 148.

Chemical News.—Portland cement. Dr. F. Vormeck, p. 262, Vol. 48.

Dingler's Polytechnisches Journal.—Ueber die Wirkung der Magnesia bei der Erhärtung der Kalk-Thonerdesilicate unter Wasser, p. 504, Vol. 198. Ueber Portland Cement mit pulverisirten Guszeisen, p. 92, Vol. 195. Steinmann's Kalköfen mit Gasfeuerung, p. 501, Vol. 198. Wolter's über Kalk und Mörtel, p. 343, Vol. 196.

Engineer.—Portland cement, pp. 22, 126, Vol. 30. Cement-testing machine of Mitchell & Parrington, p. 426. Strength of cements, p. 347, Vol. 30.

Engineering.—Cement works of J. B. White & Bros., p. 367, Vol. 9. Cement-testing machine, p. 465, Vol. 10.

Proceedings of the Institution of Civil Engineers (London).—Experiments on strength of Portland cement, p. 266, Vol. 32. Comparison between Portland and Roman cements, p. 267. Experiments as to the best mode of avoiding distortion or departure from the line of strain, p. 268. Different modes of using Portland cement in construction of sewers, p. 275. Standard of strength specified at various times, p. 278. Early conclusions as to strength of Portland cement, p. 278. Concrete sets less rapidly than neat cement, p. 278. Tensile strain required to separate bricks cemented with Portland cement, pp. 284, 285. Extracts from specifications of sewers made of Portland cement concrete, p. 304.

Jahresbericht (Wagner).—Die chemische Prüfung des Cementes (Bender), p. 363. Prüfung des Cementes (Sturtz), p. 364.

1871.

American Chemist.—On the preparation of Schott's hydraulic cement, p. 355. Chemical examination of a cement stone, p. 190. The increase of hardness of Portland cement, p. 240.

Chemical News.—To make Portland cement very hard, p. 134, Vol. 24. Chemical analysis of a cement stone, p. 287, Vol. 23.

Chemisches Central-Blatt.—Wirkung der Magnesia bei Erhärtung der Cemente, p. 150. Ransom's neuer Kunnstein, p. 336. Erzeugung von Cement aus Grunstein (Balling), p. 602. Wirkung der Magnesia in den

Cementen (Bender), p. 496. Materialien zur Darstellung der Cemente, p. 55. Zusammensetzung der Cemente, p. 719.

Dingler's Poyltechnisches Journal.—Michele und Carrington's Festigkeits-Probirapparat für Cementsteine, p. 260, Vol. 199. Studien über den Portland Cement, pp. 434, 564, Vol. 202. Chemische Untersuchung eines Cementsteins, p. 219, Vol. 200. Knapp über das Wesen der Hydraulicität der Mörtel und Mörtelartigen Erzeugnisse, p. 513, Vol. 202. Steinmann's continuirlicher Brennofen mit Gasfeuerung für Cement, p. 457, Vol. 200.

Engineering.—Cement manufacture in India, p. 393.

Proceedings of the Institution of Civil Engineers.—Experiments on Portland cement (Grout), p. 81, Vol. 32. Cohesive and adhesive strength, p. 325. Length of time necessary for the setting of heavy cements, p. 327. Probable future manufacture of cement in a concentrated form, p. 327. Table giving results of experiments on mortars of Portland cement and various kinds of sand, pp. 319, 320. Effect of modifying the present test for cement, and adding one for fineness and specific gravity, p. 324. Time allowed for setting regulated according to quantity of water used, p. 317. Deterioration of cement during a voyage to Bombay, p. 318.

Transactions of the American Institute of Mining Engineers.—Cement from blast furnace slag, p. 214.

1872.

American Chemist.—On the basic calcium carbonate in hydraulic cements, p. 467. Experiments upon Schott's hydraulic cement, p. 155.

Chemical News.—On Portland cements, p. 34, Vol. 25. Basic carbonate of lime in cements, p. 157, Vol. 26.

Chemisches Central-Blatt.—Untersuchung verschiedener Kalksteine zu Cemente, p. 633. Basisch kohlensaure Kalk in Cementen, p. 633. Wesen der Hydraulicität der Mörtel, p. 871.

Dingler's Polytechnisches Journal.—Ueber Verwendung von Hohofenschlacken zur anfertigung von Cement, p. 461, Vol. 206. Schulatschenko über basischen kohlensauren Kalk in hydraulischen Cementen, p. 335, Vol. 205. Fletcher's Mörtelmühle mit Selbstentleerungsapparat, p. 94, Vol. 203. Ueber die Verwendung von Schlackengrand statt Sand bei demselben, p. 460, Vol. 260.

Annales des Mines.—Recherches chimique sur les ciments hydrauliques, p. 233.

Transactions of the American Society of Civil Engineers.—Physical properties of cements, p. 110, Vol. 1. Cohesive strength of cements, p. 154, Vol. 2.

Jahresbericht (Wagner).—Bestimmungen der absoluten Festigkeit von Portland Cement (Th. Behrmann), p. 463. Basisch Kohlensauren Kalk in Cementen, p. 439. Portland Cement (Schott), p. 426.

1873.

American Chemist.—The manufacture of Portland cement from dolomitic limestone, p. 357.

Dingler's Polytechnisches Journal.—Erdmenger über Portland Cement, p. 286, Vol. 209. Ott über Verwendung der Hohofenschlacken zur Fabrikation von hydraulischen Cement, p. 57, Vol. 208.

Engineer.—On the strength of cement (G. F. Chautrell), p. 85, Vol. 36.

Engineering.—The Prideaux patent cement, p. 345, Vol. 16.

Mittheilungen der Technische Laboratorium (München).—Versuche über die Festigkeit von Mörtelproben aus Perlmooser Portland Cement (Bauschinger), pp. 1, 16. Versuche über die Zug und Schubfestigkeit von Ziegelsteinen und Mörtelproben aus Bonner Portland Cement (Bauschinger), pp. 17, 23.

Transactions of the American Society of Civil Engineers.—Analysis of Rosendale cements, p. 176, Vol. 2. Tests of cements, p. 153. Briquette forms and molds for testing cements, p. 155. Transverse tests of Rosendale (Norton's), Louisville, Phoenix, Allen and Diamond cements, p. 156.

Transactions of the American Institute of Mining Engineers.—Cement stone at Uniontown, Pa. Cement analyses, p. 397.

Jahresbericht (Wagner).—Portland Cement aus Kalken (L. Erdmenger), p. 514. Maschine zur Prüfung der Festigkeit der Cementziegel (Michele), p. 527.

1874.

Dingler's Polytechnisches Journal.—Ueber das Treiben der Cemente (Wolters), p. 392, Vol. 214. Portland Cement aus dolomitischem Kalk, p. 13, Vol. 211; p. 40, Vol. 214.

Engineer.—Cement Testing, p. 56; Vol. 37.

Transactions of the American Society of Civil Engineers.—Classification of cements, p. 174. On the composition of cements (Beckwith), p. 171. Cement of Hudson River Company, p. 12. Transverse tests, p. 155.

Transactions of the American Institute of Mining Engineers.—Analysis of cement, p. 397, Vol. 3.

Jahresbericht (Wagner).—Portland Cement aus dolomitischem Kalk (Erdmenger), p. 627.

1875.

Chemisches Central-Blatt.—Treiben der Cemente (Wolters), p. 89. Veränderungen des Portland Cementes durch Lagern (Erdmenger), p. 361. Verwendbarkeit des Wasserglass Bautechnik (Frühling), p. 710.

Dingler's Polytechnisches Journal.—Neues Verfahren zur Fabrikation, p. 75, Vol. 215. Ueber Veränderungen welche Portland Cement durch Lagern erleidet, p. 538, Vol. 215; p. 63, Vol. 216; p. 503, Vol. 218. Ueber Verwendung von Alkalien in der Portland Cement Fabrikation und Zerfallen des Portland Cementes, p. 503, Vol. 218.

Transactions of the American Society of Civil Engineers.—Testing machines, p. 313, Vol. 4. Cement sampling, p. 312, Vol. 4. Appliances for testing cements, p. 313, Vol. 4. Cement for masonry dam, p. 354, Vol. 3. Experiments with cements, p. 101, Vol. 4. Tensile strength of cements, pp. 99, 312, Vol. 4.

Transactions of the Institution of Civil Engineers.—Experiments on Portland cement used in the Portsmouth Dock Yard, p. 125, Vol. 41. Gauging of cement for the test bricks, p. 126. Degree of fineness to be observed in grinding, p. 126. Effect of coarse grinding, p. 127. Quality of cement not always superior on account of greater weight, p. 127. Result of inclosing cement in casks or bags after grinding, p. 128. Average strength of Portland cement at the end of seven days and thirty days, p. 128. Disadvantages of the seven-days' test, p. 129. Fairest way to test cement at thirty days, p. 129. Decrease in tensile strength from seven days to twelve months, p. 130. Average tensile strength at twelve months and at two years, p. 130. Increase of weight no indication of proportionate increase of tensile strength, p. 130. Causes of variation in weight, p. 131. Breaking tensile strain of Portland cement and sand, p. 131. Testing cement with an admixture of sand in the proportion destined for the work, p. 132. Tensile strength of Portland cement when mixed with and kept in salt water, p. 132. The chemical action of water on cement, p. 133. Conditions of manufacture, p. 134. Proportions of chalk and clay, p. 134. Proportions for a high tensile strength, p. 135. Same for slow and quick-setting cements, p. 135. Extent to which calcination should be carried, p. 136. Mechanical pulverization, p. 136. The effect of fineness upon the tensile strength of Portland cement, p. 136. Reasons why coarse cements are valuable, p. 137. Influence of quantity of water used in gauging cement, p. 138. The age of cement an important element in its use, p. 139. Necessity of uniformity of procedure with grinding and testing, p. 139. Weighing machines employed for testing the tensile strength, p. 140. Analysis of raw materials used by the Burham Cement Company and by Hooper & Co., and of the Portland cement manufactured, p. 141. Breaking strain of cement of light weight, p. 143. Tensile strength of Portland cement by wet and dry tests at seven days, p. 144. Comparison between the tensile strength of Portland cement at seven days and thirty days, p. 145. Increase in strength of Portland cement from seven days to twelve months, p. 145. Comparative tensile strength at twelve months, p. 147; at two years, p. 148. Breaking tensile strength of Portland cement in relation to weight, p. 148. Increase in tensile strength of cement and sand

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1876.

Chemical News.—Report on analyses of cements, p. 19, Vol. 33.

Chemisches Central-Blatt.—Werthstellung des Cementes (Michaelis), p. 160.

Dingler's Polytechnisches Journal.—Festigkeit von Cement, p. 310, Vol. 220. Fabrikation von Cementröhren, p. 506, Vol. 220. Bericht über die wissenschaftlichen Principien, welche den Eigenschaften und der Cemente zu Grunde liegen (Knapp), pp. 147, 236, Vol. 221. Prüfung gewerblicher Concessionsgesuche für Cementfabriken, p. 174, Vol. 221.

Scientific American Supplement.—Strength of Portland cement, pp. 712, 734.

Transactions of the Institution of Civil Engineers.—Experiments on cements at Bangalore, p. 238, Vol. 44. Adhesion of mortars to bricks and stone, p. 238. Best way of using mortars of sand and fat lime, p. 238. Proportion of actual strength to tensile strength obtained with standard briquettes of mortar, p. 240.

1877.

Chemical News.—Portland cement, p, 216, Vol. 36.

Chemisches Central-Blatt.—Werthstellung des Cementes, p. 393.

Dingler's Polytechnisches Journal.—Grundsätze für die Werthstellung des Portland Cementes, p. 220, Vol. 223; pp. 118, 287, 417, 487, Vol. 224 (Michaelis). Ueber die Festigkeitsprüfung der Cemente (Frühling), pp. 487, 655, Vol. 224. Zur Prüfung von Portland Cement (Dyckerhoff), p. 565, Vol. 225; p. 644, Vol. 226. Ueber das Treiben der Cemente (Bauschinger), p. 106, Vol. 226. Zur Untersuchung von Portland Cement (Fresenius), p. 644, Vol. 226. Patentertheilungen, p. 348, Vol. 223.

Engineering.—Testing Portland cement, p. 155, Vol. 23.

Journal of the Franklin Institute.—Hydraulic cement, 372.

Proceedings of the Institution of Civil Engineers.—The testing of Portland cement, p. 248, Vol 47. Relation between the weight and tensile strength of cement, p. 249. Summary of tests showing increase of strength with increased specific gravity, p. 249. Description of gravimeter, p. 251. Weight of one cubic foot of cement as ordinarily obtained and specific gravity, p. 252. Effect of coarseness on the strength of cement; breaking strain per square inch after seven days' immersion.

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Transactions of the American Institute of Mining Engineers.—Cement from blast furnace slag, p. 350.

Jahresbericht (Wagner).—Normaler Cement (R. Dyckerhoff), p. 769. Schachtofen zum ununterbrochen Brennen von Portland Cement mit Darreinrichtung (Hauenschild), p. 768; (Schöfer), p. 769. Ueber die Wirkung der Magnesia im gebrannten Cement, p. 771. Windsieberei, p. 772. Erhärtung von Portland Cement unter verschiedenen Bedingungen, p. 773. Bestimmungen für die einheitliche Lieferung und Prüfung von Roman Cement, aufgestellt am 12 April, 1890, vom Oesterreichischen Ingenieur und Architekten-Verein, p. 775-781. Cementbindung (Kawalewski), p. 781. Vermerthung von Kalkschlamm rückständen aus Zuckerfabriken u. dgl. zur Herstellung von Cement, p. 782. Die Herstellung von Schlackencement (Grosclaude), p. 783. Zur Herstellung von Magnesiacement, p. 784. Cementgewinnung aus Schlacke, p. 69, Vol. 279. Cement zum Niederbringen der Schachte, p. 200, Vol.

279. Ueber den Werth der Heisswasserproben bei der Prüfung von Cement und hydraulischen Kalk, p. 182, Vol. 280. Cement-untersuchungen, p. 210, Vol. 280. Ueber die Untersuchung und des Verhaltens von Cement, p. 114, Vol. 281. Normen für einheitliche Lieferung von Cement, p. 114. Volumebeständigkiet unter Wasser, p. 114. Feinheit der Mahlung: Zug— und Druckfestigkeit, p. 114. Bestimmung des Kalkgehaltes in Kalkmörtel, p. 115. Vorschrift des Vereins deutscher Portland Cement Fabrikanten bezieglich ihrer Fabrikate, p. 115. Apparat von Amsler-Laffon, p. 116. Hochdruck-dampfmethode zur Cementprüfung, p. 116. Verhalten der Cemente vor und nach der Verwändung, p. 138, Vol. 281. Ueber Umstände, unter welchen die Erhärtung nicht stattfinden kann, p. 140. Volumen-veränderung, Schäden, Uebelstände, p. 163. Wirkung der Magnesia auf Cemente, p. 165. Einwirkung des salzhaltigen Wassers und der Sodalösung auf Cement, p. 167. Durchlässigkeit von Cement morteln, p. 167. Mittheilungen aus der Cement-technic von Dr. A. Busch, p. 116, Vol. 282. Wirkung der Magnesia in Portland Cementen, p. 120, Vol. 282.

1891.

The Chemical News.—Properties of cements, p. 38, Vol. 63.

The Engineer.—Cement drying and burning apparatus, p. 53, Vol. 71. The manufacture of cement, p. 85, Vol. 71. Stokes Portland cement plant, pp. 76, 126, 146, 164. A new era in cement testing, pp. 391, 412. Michaelis cement-testing machine, p. 493. Testing normal sand for cements, p. 195, Vol. 72. Cement testing, p. 15.

Engineering.—Cement-testing machines, p. 738, Vol. 51. Cement-grinding machinery, p. 131, Vol. 51.

Engineering News.—Portland cement plant, p, 280, Vol. 25. Microscopical tests (Brown), p. 481, Vol. 26. Machine for briquettes, p. 138, Vol. 25. Frost-proof, p. 203, Vol. 26. English testing machine, p. 30, Vol. 26. Standard sand, p. 286, Vol. 26. Effect of salt in mortar, p. 48, Vol. 26.

La Genie Civil.—Appareil continue par le fabrication de ciment de Portland, p. 333. Moyer de rendre le ciment de Portland inattaquable par la gelee, p. 266. Ciment: Les usines de ciment millot et cis étude geologique et industrielle (Mawry), p. 121.

Journal of the Society of Chemical Industry.—Action of solution of magnesian sulphate on cement, p. 465. Apparatus for the manufacture of cement, p. 644. Proceedings of German cement makers, p. 390. Rapid method of testing soundness, p. 931. Wearing properties for paving purposes, p. 465. Comparative examination of Portland, Puzzolano, and Roman cements, p. 140. Hot tests for cements, p. 255.

Proceedings of the Institution of Civil Engineers.—Desirability of adopting a chemical test for Portland cement, p. 175, Vol. 103. Slag cement, p. 427, Vol. 105.

Scientific American Supplement.—Description of a new cement tester, p. 12526. Cement testing, p. 12838. Portland cement, p. 13308.

Transactions of the American Society of Civil Engineers.—Cement used as grout for filling voids in riprap under water, p. 230, Vol. 24. Deterioration of cement by age, pp. 269, 286, Vol. 25. Neat tests *vs.* sand tests for Portland cement, pp. 295, 301, 303, Vol. 25. Notes on cements, mortars, and concretes, p. 259, Vol. 25. Seasoning of Portland cement, p. 282, Vol. 25. Setting of Portland cement, p. 279, Vol. 25. Testing of cements (C. B. Brush), pp. 270, 280, Vol. 25. Tests of cements required by United States Navy Department, p. 261, Vol. 25.

Jahresbericht (Wagner).—Normal sand, p. 729. Wirkung von Magnesia im gebrannten Cement (R. Dyckerhoff), p. 793. Verfahren zur Prüfung der Volumbeständigkeit von Portland Cement, p. 796. Der Rost für Schachtöfen (F. Kawalewski), p. 799. Zeitler's Cementbrennöfen, p. 799, Guthmann's (p. 800), Dietzsch's (p. 800), Schöfer's (p. 800), Steinmann's Schachtöfen mit Gasfeuerung (p. 801). Gyps im Cement (L. Erdmenger), p. 801. Prüfung von Cement (L. Erdmenger), p. 803. Glasplattenkuchenprobe, p. 804. Die Heisswasserprobe für Cementprüfen (Deval und H. Le Chatelier). p. 804. Ueber vergleichende Untersuchungen von Cementen (D. Lameson und H. Remley), p. 804.

ATTENTION IS ALSO DRAWN TO THE FOLLOWING WORKS PUBLISHED UPON CEMENT.

"Kalk, Gyps und Cement," by E. Böhmer und F. Newmann. Weimar, 1870.

"Patentirte Brennöfen—Anleitung zur Anlage der Zweckmässigsten Brennöfen für Thonwaaren, Kalk and Cement." Berlin, 1871.

"On limes, hydraulic cements, and mortars," by Gen. Q. A Gillmore, U. S. A. New York, 1870.

"Notizblatt des deutschen Vereins für Fabrikation von Ziegeln, Thonwaaren, Kalk und Cement," by H. Seger. Berlin, 1873.

"Analyses chimiques et essois de resistance de matèriaux de construction pierres de taille, chaux, ciments, plâtres, faits à l'ecole des ponts et chaussées sur la direction de MM. Léon Durand-Claye et Michelot, ingenieurs en chef des ponts et chaussées." Paris, Dunod, publisher.

"Die Bedeutung der Gasfeuerung und Gasöfen für das Brennen von Porcellan und Cement," von H. Stegmann. Berlin, 1877.

"Lehrbuch der Kalk, Cement und Gypsfabrikation," J. F. Rühne, Braunschweig. 1877.

"Jahrbuch über die Leistungen und Fortschritte der Thonwaaren, Kalk und Cement Industrie," von H. Zwick. Berlin, 1879.

"Hydraulischen Kalk, und Portland Cement nach Rohmaterialien, physikalischen und chemischen Eigenschaften, Unterauchung, Fabrikation und Werthstellung," von H. Zwick. Leipzig, 1879.

"On Portland cement," by James Forrest. London, 1880.

"Portland cement," by W. Maclay, C. E. New York, 1880.

"Science and art of the manufacture of Portland cement," by Henry Reed. London (Spon & Co.).

"Experiments on the strength of cement, chiefly in reference to the Portland cement used in Southern main drainage works," by John Grant. London.

"Calcaires, chaux, ciments, mortiers," par M. Duquesnay, ingenieur des manufactures de l'etat. Paris, 1883 (Dunod, editeur).

"Traité Pratique de la Fabrication du Ciment de Portland," par A. Lipowitz. Paris, 1883 (Lacroix, editeur).

"A practical treatise on natural and artificial concrete, its varieties and constructive adaptations," by Henry Reed. London (Spon & Co.).

"Résumés sur l'architecture et les sciences qui s'yrattachent," par A. Gouilly. Paris, (E. Bernard, editeur).

"Guide du chaufournier et du plâtrier, du fabricant de ciments, betons et mortiers hydrauliques," par Emile Lejeune. Paris, (Tignol, editeur).

"Maconnerie (chaux et ciments)," par J. Denfer, professeur à l'ecole centrale. Paris (Baudry, Editeur).

"A text-book of the materials of construction," by R. H. Thurston. (Wiley & Sons) New York, 1885.

"Zement und Kalk, von Rudolf Tormin. Weimar, 1886.

"Kalk, Gyps, Cement," von Fr. Neumann. Weimar, 1886.

"Lexicon der Verfälschungen." Dammer, 1886.

"Étude pratique sur le ciment de Portland," par E. Candlot. Paris, 1886.

"Die chemische Technologie der Mörtelmaterialien," von G. Feichtinger. Braunsweig, 1886.

"Ciments et chaux hydrauliques—fabrication, proprietes, emploi," par E. Candlot. Paris (Baudry, editeur), 1891.

"Der patentirte Sonnetsche Gas— Kanal-Ofen unter besonderer Berüchsichtigung d. neuen Fabrikations Verfahren von Portland Cement" Bernburg, 1887.

"Die Fabrikation Stein, Cementgüsse," von E. Höfer. Vienna, 1887.

"Notes on Concrete," by John Newman. London (Spon & Co.).

"Chem. Grundbegriffe, Baumaterialienkunde Ziegel, Kalk-Gyps und Cementfabrikation," von Keller. Leipzig.

"Kalk, Gyps, Cementkalk und Portland Cement in Oestereich-Ungarn," von Carnawsky. Vienna.

"The testing of materials of construction," by W. C. Unwin, F. R. S. London, Eng., 1888.

"Étude sur la fabrication et les proprietes des ciments de l'Isèri," par M. A. Gobin, ingenieur en chef des ponts et chaussées. Paris, 1889 (Dunod, editeur).

"Protokoll der Verhandlungen des Vereins deutscher Cement-Frabrikanten." Berlin, 1890, 1891, 1892.

"Mineral resources of the United States," by David T. Day. Washington, D. C, 1891. "Natural and artificial cements," pp. 527–589.

"Der Portland Cement und seine Anwendungen im Bauwesen; Bearbeitet im Auftrage des Vereins deutscher Portland-Cement-Fabrikanten." Berlin, 1892.

"A manual of lime and cement," by A. H. Heath. London, 1893 (Spon & Co.).

"Lehrbuch der Technische Chemie," von Dr. H. Ost. 1893, pp. 179-190.

"Repertorium der Technischen Litteratur," von Bruno Kert. Leipzig, 1870–1892.

"Chemisch-technische Analyse," von Dr. Jul. Post, pp. 16–29, Vol. 2. Braunsweig, 1891.

"Chemisch-technische Untersuchungsmethoden," von Dr. F. Böckmann, pp. 683–727, Vol. 1. Berlin, 1893.

"Thonindustrie-Zeitung," 1870–1892. Berlin.

"Zeitschrift für Angewandte Chemie." 1889–1892.

"Chemiker-Zeitung, Repertorium." 1892.

"Mittheilungen des deutschen Veriens für Fabrication von Ziegelen, Thonwaaren, Kalk und Cement." 1892.

"Deutsche Töpfer-u-Ziegler Zeitung." 1892.

"Deutsche Bauzeitung." 1892.

"A treatise on masonry construction," by Ira O. Baker. (Wiley & Sons) New York, 1893.

STUDIES OF THE PHENOMENA OF SIMULTANEOUS CONTRAST COLOR; AND ON A PHOTOMETER FOR MEASURING THE INTENSITIES OF LIGHTS OF DIFFERENT COLORS.*

BY PROF. ALFRED M. MAYER.

IT is often desirable in the study of simultaneous contrast colors to have large surfaces colored by contrast, so that we can the better match the colors of these surfaces with rotating colored disks and thus arrive at quantitative statements of their hues. This is especially desirable in ascertaining the hues of the light of flames, of the Welsbach incandescent lamp and of the arc electric light when compared with daylight, or, when compared one with another. The result of many experiments is the apparatus described in the following section, and which is useful for this purpose.

Screen for Ascertaining the Hues of Lights and the Contrast Colors of These Lights.—A ring is formed of white cardboard by cutting out a central opening of 12 centimeters in diameter in a disk of 22 centimeters in diameter. This ring has a breadth of 5 centimeters. Another ring is made similar to this one, except that it has four narrow radial arms to support a disk of thin translucent *white* paper,† 35 centimeters in diameter. This paper disk is placed between the rings, which are then fastened together and screwed to a thin rod, on a stand, as shown in Fig. 1.

Place the screen, thus formed, in front of a petroleum lamp and exclude the daylight from the side thus illuminated. The other side of the screen is illuminated by the light of the sky admitted through a distant window. The cardboard ring is thus illuminated on one side only by the lamp; on the other side, only by the daylight. The translucent paper transmits the lamplight to the side facing the window, while it transmits the daylight to the side facing the lamp. On the side of the screen facing the window the cardboard ring appears cyan-blue while on the side facing the lamp the ring appears orange-yellow.

* From the *American Journal of Science*, Vol. XLVI., July, 1893.

† Trials with many kinds of paper showed that a white linen tracing paper was the best. It is not possible to describe this so that one may be sure of selecting a similar paper. It was obtained of Keuffel & Esser, Fulton Street, New York, and sold as "No. 202 Alba tracing paper."

Hues of the Sides of the Ring.—An idea of the hues and intensities of these colors, which cause astonishment even in those who are experimenters in chromatics, will be given by the description of the following experiments.

By means of a Bunsen photometer disk I adjusted the distance of the lamp from the screen so that I obtained, as nearly as I could judge, equal illumination of the sides of the screen. I then found that the blue was matched in a rotator by a disk having a sector of 60 parts of the circumference of Prussian blue, with a sector of 10 parts of emerald-green and a sector of 30 parts of white cardboard. The blue was that of one of the many colored disks given me by

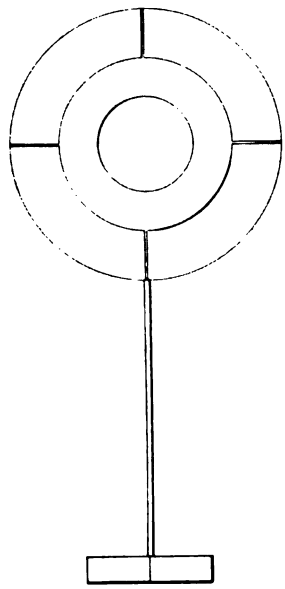

Fig. 1

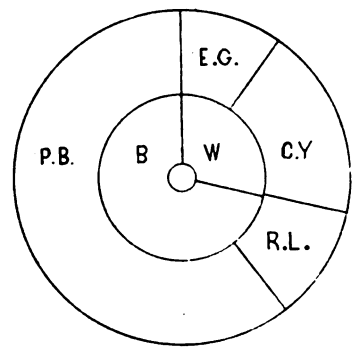

Fig. 2

Prof. O. N. Rood, and was marked "Blue between cyan-blue and the ultramarine of the physicist, but nearer the latter. Near F and on its more refrangible side. Made with Prussian blue." The blue on this disk appeared as saturated in hue as could be made by the pigment.

The match of the color of the side of the ring facing the lamp, L in Fig. 3, was obtained by placing a silvered mirror, M, so that the reflection of this side of the ring, S, was seen close to the rotator, R.

The color of the cardboard ring facing the lamp was matched by the rotation of a disk formed of 50 parts of chrome-yellow, 30

parts of red lead (red orange), and 20 parts of white cardboard. Such appears to be the hue of the light of a petroleum flame when compared, in this manner, with the light of the sun.

The petroleum flame used in these experiments was that of a Belgian burner, giving about 35 candles. The daylight was obtained from a window 85 centimeters square; the lower half of which when viewed from the screen, was occupied by the snow-clad surface of an opposite hill. The day was very clear, and the sky very slightly tinted with blue.

The Colors of the Sides of the Ring of the Screen are Complementary.—I combined the Prussian blue, emerald-green, chrome-yellow, and orange-red on a disk on the rotator, and found that when the disk was formed of sectors having 60 parts of Prussian

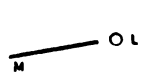

Fig. 3.

Fig. 4.

blue, 11 of emerald-green, 19 of chrome-yellow, and 10 of red lead, I obtained a gray which was exactly matched by a central disk formed of 71 parts of dead ivory-black and 29 of white cardboard. See Fig. 2. These measures gave the following equation:

$$\left\{\begin{matrix}60\text{ Prussian blue}\\11\text{ Emerald-green}\end{matrix}\right\} + \left\{\begin{matrix}19\text{ Chrome-yellow}\\10\text{ Red lead}\end{matrix}\right\} = \text{Gray}\left\{\begin{matrix}71\text{ Black}\\29\text{ White}\end{matrix}\right\}$$

It is rather difficult to get the exact match on the rotating disk of the hues on the front and back of the cardboard ring of the screen on account of the illumination of these surfaces. The rotator must be placed nearer the window than the screen so that it is well illuminated.

The equation shows that the cyan-blue of 60 parts of Prussian blue + 11 of emerald-green is complementary to an orange-yellow

of 19 of chrome-yellow + 10 of red lead. The hue of this orange of the lamp side of the ring, as given by the rotator was 50 chrome-yellow + 30 red lead + 20 white, which mixture is approximately in the proportion of 19 to 10. The correspondence of the two experiments is, I suppose, about as near as could be expected from the difficulty of matching the illuminated hues of the ring of the screen.

The small central disk on the rotator gave a gray of 71 parts of ivory-black + 29 of white cardboard, which matched the gray given by 71 parts of cyan-blue + 29 parts of orange. Calling the intensity of the orange 100, we have $100 \times 29 = 71\,I$, which gives for I (the intensity of the cyan-blue), only 40.8 per cent. of that of the orange.

The orange-yellow of the side of the ring facing the lamp and of side of the translucent paper facing the daylight, is complementary to the cyan-blue of the side of the ring facing the daylight and of the side of the translucent paper facing the lamp.

In Fig. 4, L is the lamp; S, the screen which in this experiment is deprived of the border of translucent paper; W, the window; M, a silvered mirror which reflects the back of the screen to the eye which looks through an achromatized double refracting calc-spar prism at C.S., and sees two images of the side of the screen reflected from the mirror and two images of the side of the screen facing the window. By suitably inclining and rotating the calc-spar prism these images may be brought into the positions shown in Fig. 5, in which A represents one of the images of the side of the screen facing the window; B, the other image of the same; C is one of the images of the side of the screen facing the lamp and seen by reflection from the mirror.

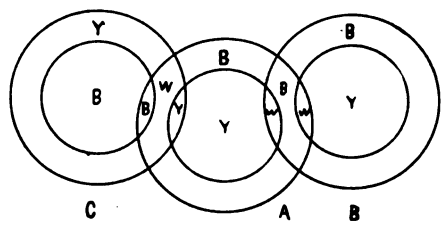

Fig. 5.

The overlapping of these images, when the illumination is properly adjusted, gives the following results, as shown by the letters in Fig. 5, where B stands for cyan-blue, Y for orange-yellow, and W for white. The translucent paper Y of B overlaps the ring of A and gives white, and the blue of the ring of B overlaps Y of the translucent paper of A and gives white. In the same manner the orange-yellow of the cardboard ring of C overlaps the blue of

the ring of A and gives white. Where the ring of C overlaps the translucent paper of A there is a more intense orange, and when the blue of the translucent paper of C overlaps the blue of the ring of A we have a more intense blue. On bringing B of the translucent paper of C over Y of the translucent paper of A we have white.

Experiments on the Complementary Colors of Gratings.—Out of thin cardboard, such as is used for thin visiting cards, I cut gratings with a dividing engine. See Fig. 6. The widths of the spaces cut out of these gratings exactly equaled the breadths of the cardboard left in the grating. Gratings were thus made having spaces of 1, 2, 3, 4, and 5 millimeters. The cardboard is rendered opaque by coating one side of it with ivory-black in dilute shellac varnish. After it has dried, the cardboard is well flattened before it is fastened to the surface of a piece of hard wood on the dividing engine. The cutting edge of the cutter for this work must have a very acute angle. I made one by grinding down a rod of Stubs' steel. Heating this to a dull cherry-red and then forcing it into a large ball of beeswax gives the edge of the cutter the required temper, without the necessity of subsequently "letting it down." The blackened

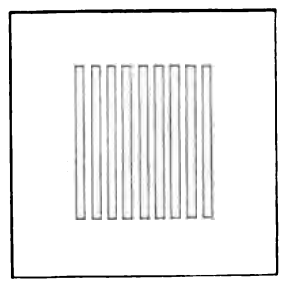

Fig. 6.

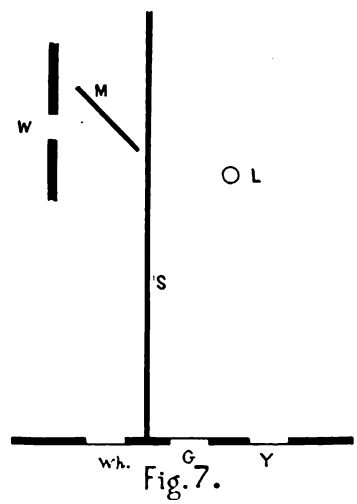

Fig. 7.

side of the gratings was covered with the "Alba tracing paper." The grating was mounted back of an opening in a black cardboard screen, so that only the white grating was exposed. Two other black screens, Wh and Y of Fig. 7, having openings of the same size as the grating and covered on the back with the translucent paper, were placed on either side of the grating G. In Fig. 7, L is the lamp. The window is on the other side of G. The screen S divides the apparatus so that the light of the window W reflected

by the mirror M onto the screen Wh cannot fall on G or on Y, which are only illuminated by the lamp L.

The translucent paper of the grating G and of the screen Y appear orange-yellow. The bands of white cardboard of the grating appear cyan-blue. The translucent paper of the screen Wh is white.

Sit a little to one side of the grating so as not to intercept the light from the window, and look at the grating through the calc-spar prism. Rotate it till the blue bands of the grating are superposed on the orange bands, when, if the surface of the grating is equally spaced, the superposed surfaces appear white when compared with the white of the screen Wh. Without the screen Wh the eye has no term of comparison and may take a yellowish white for white. The illumination of the screen Wh should be made equal that of the superposed images of the grating.

When this experiment is carefully made, with the proper illumination, the effect is surprising when, in favorable conditions, on rotating the prism you see the grating actually obliterated with no bands visible, but only a uniform white surface. The grating with spaces of 3 millimeters gave the best results.

In experiments with the screen, Fig. 1, formed of the cardboard ring and the translucent disk, it is easy, by altering the relative intensities of the daylight and lamplight and by changing the distance of the lamp from the screen, to produce great changes in the saturation of the contrast colors. Indeed, I have sometimes thus obtained, towards nightfall, a cyan-blue so saturated in hue that little or no white was required in the disk of the rotator to match the color on the ring. In the same manner similar changes in color have been observed in the hue of the ring illuminated by the lamp.

On illuminating one side of the screen by daylight and the other by the white light of a Welsbach incandescent lamp, and then placing colored glasses or films of colored gelatine between the screen and the Welsbach lamp, effects of contrast are obtained which are so readily imagined by the physicist as to require no description; but they are worth viewing.

Increase of the Purity and Luminosity of the Contrast Colors by a Rotating Screen.—Make a disk of white cardboard of 27 centimeters in diameter, with eight sectors cut out of it, and cover it with translucent paper so that the paper extends beyond the disk and makes a border 3 centimeters wide. A circle of 8 centimeters in diameter is left in the center of the disk and a ring of 1½ centimeters on its border. This disk is shown in Fig. 8, but with only six sectors. It should have eight. It is placed between the lamp and the window, and rotated with a velocity of one revolution in about 1¼ seconds, while it is viewed on the side facing the window. The blue sectors thus take successively the places just before occupied by the sectors of orange-yellow, and the effect is to heighten

the contrast color in such a remarkable manner that the blue sectors by their more intense color appear separated from the rim and central circle and appear in a plane farther from the eye than the plane of the center and rim. On the side of the disk illuminated by the lamp the same effects are produced, only they appear more marked. A change will also be observed in the hue of the advancing and following edges of the sectors, on both sides of the disk; the advancing edges appearing more saturated in hue than the following edges.

A Mode of Observation by which Contrast Colors are Intensified.—Simultaneous contrast colors are generally viewed by placing gray or tinted surfaces on colored grounds, or by the juxtaposition of colored surfaces. The effects thus produced are of such constant occurrence in the paintings of artists, and in colored fabrics, that their study is of great interest. The contrast colors thus produced have generally been studied by simply placing on a colored ground smaller gray or tinted surfaces and observing these

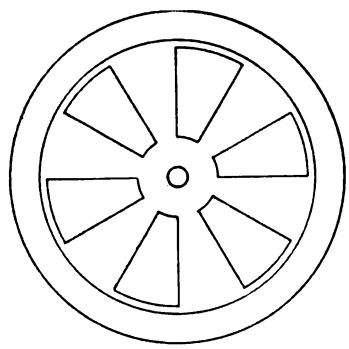

Fig. 8.

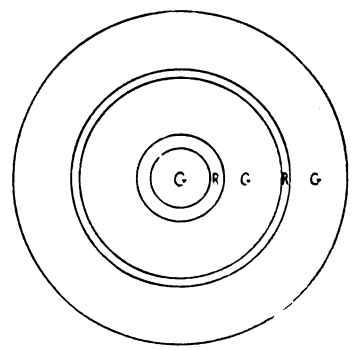

Fig. 9

with the unaided eye. This method has been improved by H. Meyer,* who viewed the gray on the colored ground when both were covered with white transparent paper.

The mode of observation I have devised for the study of contrast colors is as follows: A glass tube of 2.7 centimeters in interior diameter and 10 centimeters long is coated on the outside with black japan varnish, so as to have reflection only from the interior surface of the tube. A ring of 3 centimeters in diameter with a central opening of 2 centimeters is cut out of gray paper. The gray of this ring was matched on the rotator by a disk having 57 parts of ivory-black and 43 parts of white Bristol board. This ring, placed on a surface of emerald-green, appears of a rose

* Pogg. Ann., XCV., 170.

color. If at the distance of distinct vision we look at the ring through the tube we shall see the ring by direct vision inclosing a circle of green and surrounded by a ring of emerald-green, and this inclosed by a rose-colored ring, produced by reflection from the gray ring from the interior of the tube, and surrounding this ring is another of emerald-green, as shown in Fig. 9; in which R and R are the red rings and G, G, and G, the circle and the two rings of emerald-green.

The hue of the rose-colored rings as seen through the tube is much more intense than the hue of the ring viewed on the emerald ground with the unassisted eye. Experiments made with the aid of an achromatized calc-spar prism, and by matching on a rotating disk the colors of the gray ring on an emerald-green ground showed that the intensity of the contrast color, as seen with the reflecting tube, is nearly double of what it is when viewed by the eye alone. The color of the ring when viewed by the unassisted eye was matched on the rotator by a disk having 30 parts of Chinese vermillion + 7 of "Hoffman's violet R. R. R." + 34 parts of ivory-black + 29 of white Bristol board. As seen through the reflecting tube the match appeared to be given by 57 of Chinese vermillion + 15 of "Hoffman's violet R. R. R." + 28 of white Bristol board.

Another tube, 4.5 centimeters in diameter and 18 centimeters long, gave excellent results, with two reflected rings, and on nearer vision, with four reflected rings. A tube, suitable for these experiments, is selected by closing one of its ends by a disk of cardboard having a pinhole at its center. When the end with the pinhole faces the sky and we look through the other end we see bright rings caused by the reflection of the light of the pinhole from the surface of the tube. If these rings are circular and concentric the tube is of circular section and its axis is a right line.

The value of this mode of observation is shown by the following experiments. Place the ring of gray paper, or, a circle of gray paper, about 1½ centimeters in diameter, on a surface painted with cobalt-blue, not too saturated. The gray ring or circle appears of an orange tint. Place a similar gray ring or circle on a surface lightly washed with emerald-green, it appears pinkish. The difference between the hues of the ring when viewed on the cobalt-blue and on the emerald-green though decided is not strongly marked; but if viewed through the reflecting tube the ring on the cobalt-blue appears of a rather intense orange and the ring on the emerald-green appears of a rose color. When so viewed the difference in these hues is strongly marked.

Pieces of cardboard, painted with the following colors, were arranged in pairs. Orange-yellow on the less refrangible side of D, and orange-yellow on the more refrangible side of D. Greenish yellow and yellowish green, both made with gamboge and Prussian blue. Purple of violet end of the spectrum with added red, made with "Hoffman's violet R. R. R.," and violet between G

and H, Young and Müller's fundamental color. Place a pair of the colors, as given above, side by side, and on each put a gray ring with a reflecting tube over each ring. When viewed by the unassisted eye the differences in hue are slight and difficult to define; but when viewed in rapid succession through the adjoining tubes the differences in hue are decided, and may be readily matched in color with disks on the rotator.

The Duration of the Time of Vision Necessary to Perceive Contrast Color.—A square screen was made, as shown in Fig. 10, with a square of cardboard in its center, 8 centimeters on the side, surrounded by a square of translucent white paper, 35 centimeters on the side. This screen was placed between the petroleum flame and the window so that its sides were equally illuminated. On the side facing the window the central square appeared cyan-blue. One-half of this square was covered by a strip of paper so tinted with orange-yellow that it appeared gray when in juxtaposition with the other blue half of the square.

On a rotator was placed two superposed black disks of the same diameter (25 centimeters). Near the periphery of each disk was cut out an annular slot, 4 centimeters long and 6 millimeters wide,

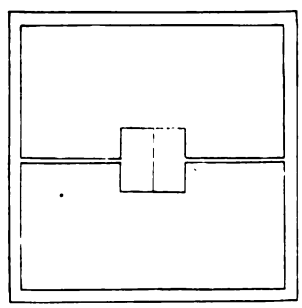

Fig. 10.

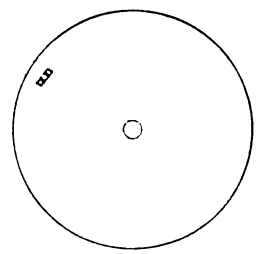

Fig. 11.

as shown in Fig. 11. By turning one of these disks on the other the opening of this slot could be varied from 4 centimeters to nothing. The rotator is so made that the time of a rotation of the disk can be held uniform and also accurately measured. On gradually narrowing the opening in the slit the duration of vision of the blue and gray square was reduced to $\frac{1}{1600}$ of a second, when the blue half of the square could not be distinguished from the gray half.

When the screen was illuminated by a more orange light, obtained by placing a sheet of orange gelatine between the lamp and the screen, the gray and blue were not distinguishable when the duration of vision was $\frac{1}{1300}$ of a second.

In these experiments I only got 11.6 flashes of light from the screen in a second, while the number of flashes required to banish all flickering from the screen was accurately measured as 46 in a second with the illumination of the lamp alone, and 42 in a second when the lamplight traversed the orange gelatine film. These experiments show, what is well known—viz., that as the intensity of the light diminishes the duration of no perceptible change in the intensity of the residual impression increases. I found that the sensation of the light from a white cloud, seen, near noon, through a north window on a clear day lasts only $\frac{1}{68}$ of a second before the residual effect diminishes.

A gray ring was placed on an emerald-green ground facing the light from a bright white cloud. When viewed through the opening in the rotator the ring appeared pink on the green ground till the duration of the vision of the ring was reduced to $\frac{1}{8380}$ of a second, when the ring ceased to be visible on the emerald-green ground; but so long as it was visible the contrast color was visible. I found that 43 flashes per second were necessary to render the vision of the pink ring and green ground steady, without the least flickering, while only 11.6 flashes per second were obtained in determining the $\frac{1}{8380}$ of a second as the time when contrast color ceased to be visible. The fact that the contrast color of the ring remained till the ring could not be distinguished from the green ground gave the opinion that I ceased to obtain contrast color because the narrow slit used gave too little light to the eye. On doubling the width of the slit and doubling the velocity of rotation the contrast color of the ring reappeared, though the duration of vision was the same as in the former experiment.

Experiments on Simultaneous Contrast Colors Produced by the Flash of the Electric Discharge.—The foregoing experiments having proved insufficient to form any opinion as to the time of vision necessary to perceive simultaneous contrast color, I made the following experiments with the light obtained by the discharge of a Holtz induction machine.

1. The gray ring was placed on the emerald-green ground near a Holtz machine, which gave a very bright flash of 8 centimeters long. The condensing surface on the two jars connected with the electrodes of this machine equaled 135 square centimeters. Prof. O. N. Rood* measured the duration of the flash of Leyden jars of 738 and 71 square centimeters of surface, charged by an inductorium. The durations of the discharges of these jars were respectively $\frac{1}{5,700,000}$ second and $\frac{1}{25,000,000}$ of a second. From these measures I infer that the duration of the flash of the Holtz machine did not exceed the $\frac{1}{10,000,000}$ of a second. With short striking distances between the electrodes the flash is formed of several sepa-

* *American Journal of Science*, September, 1871.

rated acts, as shown by Henry,* Feddersen,† Rood,‡ and Mayer.§ In the case of the discharge of a large inductorium the writer(§) has shown that when the striking distance between brass ball electrodes is only 1 millimeter, with a Leyden jar of 242 square centimeters of surface in the circuit, the discharge lasts $\frac{1}{14}$ of a second, and is formed of over 120 separate sparks; but as the striking distance is increased the discharge is formed of fewer and fewer components, till at a striking distance between 1 and 2 centimeters the discharge is reduced to a single flash. In the following experiments the striking distance is 8 centimeters, and a single flash was given, whose duration we may safely assume was less than $\frac{1}{1.000.000}$ of a second.

In a dark room, at night, the flash of this machine gave vivid contrast colors. The gray ring appearing bright pink on an emerald-green ground, and of a bright yellow on an ultramarine ground. The after-images of these effects lasted about ½ of a second.

2. A rod was placed in front of a white cardboard and the shadow of the rod was formed on the screen by a candle. The

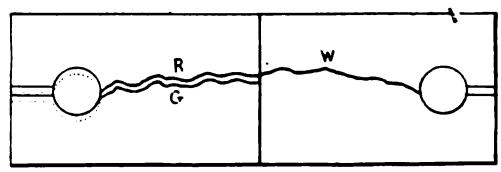

Fig. 12.

distance of the candle was such that the white cardboard appeared equally brilliant when illuminated only by the candle, or only by the electric flash. At the moment of the flash the appearance presented was very remarkable. From the shadow of the candle appeared suddenly to shoot a dark screen, which had superposed the shadow of the candle, and which shot to the side of the shadow and appeared of a bright golden orange, while the apparently uncovered shadow of the candle appeared of a brilliant cobalt-blue; to my eye exactly as though an opaque screen had been suddenly removed from a slit in the shutter of a darkened room, which slit was covered by a piece of cobalt glass.

3. A square of thin green glass, 4 centimeters by 6 centimeters, was placed on a piece of thin silvered glass, 4 centimeters by 12 centimeters, so that the edges of the green glass and of the silvered glass coincided. This arrangement gave a surface, half of silvered

* *Proceedings* Amer. Phil. Soc., 1842.
† Pogg. Ann., Vol. CXVI., p. 132.
‡ *American Journal of Science*, October, 1872.
§ *American Journal of Science*, December, 1874.

mirror, half of green glass. This apparatus was so placed that the electrodes of the machine and the flash were reflected from it to the eye. The room was dark. At the moment of the flash its reflection appeared as in Fig. 12. On the mirror the line of the discharge was white; W in the figure. The continuation of this line on the surface of the green glass appeared red (R in figure), though really white. In front of and parallel to this line was a green line G produced by the light of the flash reflected from the surface of the silvered mirror, and having traversed twice the thickness of the green glass. In this experiment we obtain contrast colors in the source of light itself.

The explanation of the phenomena of simultaneous contrast colors, as generally given in works on chromatics, is that they are due to "error of judgment," to "deception of judgment," or to "fluctuation of judgment." The reasoning given may be convincing if all the conditions really exist which the writers assume to exist in their explanations of these phenomena. One of these conditions is that a judgment can be formed in the minute interval of time only necessary in which to perceive contrast colors. In the experiments just described with the electric flash we have *apparently* instantaneous perception of the contrast colors in the gray ring placed on the green and ultramarine grounds, in the candle and electric-light shadows, and even in the very flash itself when this is seen reflected from the top surface of a green glass and from the mirror on which the green glass rests.

Many careful experiments made by me and others, using as chronometer three pairs of forks of the octave of UT_6, giving respectively 10, 12, and 15 beats per second, showed that certainly the interval between the flash and the perception of the colors was less than $\frac{1}{15}$ of a second. Indeed, on viewing the flash and the illuminated surfaces at the same time, or, hearing the discharge and viewing only the illuminated ring, *no interval could be detected* by this mode of observation as existing between the instant of the flash and the perception of the colors, and we certainly could have detected a shorter interval than $\frac{1}{15}$ of a second had it existed.

It is here to be noted that although the after-images of the contrast colors in these experiments with the electric flash lasted about ½ of a second, yet the most careful scrutiny could detect no change in sensation at and immediately following the flash. The contrast colors, so far as I and others observed, appeared at the moment of the flash. After the instant the image of the flash is formed on the retina there exists, no doubt, an interval of time before we are conscious of the stimulus, whose effects are seen rapidly to rise and then more gradually to fall, falling with two oscillations in intensity, so that all the events of the phenomenon take place in about ½ of a second. However, no vague impression of surfaces merely differing in illumination and then suddenly changing into a color and its contrast color could be de-

tected. I think that this interval of no color sensation, if it exists, must be of exceedingly short duration; but such a period of light without color cannot be detected, and if it cannot be perceived, then, so far as we are concerned, it appears to me, that there can be no hesitation in the perception of the colors, and no "fluctuation of the judgment" and "dividing between two images the difference in color which really exists" before the mind reaches its conclusion as to the character of the colors.

The following experiments were separately made on three persons between whom no communication had passed as to the nature of the experiments to be tried on them. I placed a gray ring on an ultramarine disk in front of the Holtz machine and requested the observer, who had implicit confidence in my truthfulness, to describe to me as accurately as possible the exact hue of the pink, or rose color, or red he would see on a green ground at the instant of the electric flash. Each observer at once said: "It is not pink, the ring appears yellow on a blue ground." Now in each of these experiments the observer was prepared by my pardonable lying, to see red on a green ground, and to see yellow on a blue ground his mental condition of anticipation to see red on a green ground was first removed, then a new departure was taken and a judgment formed which resulted in his seeing yellow on a blue ground, and all that in a minute interval of time.

I do not know if psychologists have come to a conclusion as to the smallest interval of time necessary to form a judgment, either true or false, or in which to have a "fluctuation of the judgment," or in which "to exercise judgment and divide between two colors the difference in colors which really exist." If such mental operations can be performed in the millionth, the thousandth, or even in a few hundredths of a second, then the explanations of these phenomena, as generally given, may be convincing.

Von Bezold in his "Theory of Color," Boston, 1876, in explaining the fact that a rod seen by reflection from a piece of green glass laid on a mirror gives two images, one green the other red, says: "As the observer does not *know* which of the two images is the colored one, he exercises his judgment and divides between the two images the difference in color which really exists." Now this experiment is similiar in its conditions and in its effects of contrast color to the one I made on the contrast colors of the electric flash, when the same colors were distinctly seen apparently at the moment of the discharge. Can one "exercise his judgment and divide between the two images the differences in color which really exists" in an interval of time which is less than $\frac{1}{16}$ of a second?

In the experiment of the colored shadows cast by the candle and by daylight, these colors are explained by Von Bezold (pp. 152, 153), as follows: "The spot occupied by the blue shadow is illuminated by the *white daylight*, the larger white surface by *daylight and by candle-light*, the other shadow by candle-light only. It might

be presumed, therefore, that one of the shadows would appear white, the other yellow. This is not the case, however; for *knowing* the surface to be white we still take it to be white after it has really received the yellow light of the candle. Our judgment is led astray regarding white, and hence we believe the place occupied by the second shadow to be blue, although it is actually white." Helmholtz ("Lectures," N. Y., 1873, p. 267), says: "Thus in the experiment described above of colored shadows thrown by daylight and candle-light the doubly illuminated surface of the paper being the brightest object seen gives a false criterion for white. Compared with it, the really white but less bright shadow thrown by the candle looks blue." These explanations assume knowledge and conditions which are not essential. If this knowledge and these conditions were necessary to see the phenomena, then these explanations of the phenomena might be convincing; but the conditions they assume are not necessary. The following experiments show that there is no necessity at all in "knowing the surface to be white," or to see "the doubly illuminated surface of the paper."

The experiment of the colored shadows cast by the candle and by daylight was arranged behind a screen, so that no one could divine what was there. A tube blackened on the inside went obliquely through the side of the screen, and was so adjusted that the circular field of view through the tube was entirely filled by equal portions of the two shadows, which formed two semicircles, one colored orange, the other blue. The two persons on whom I experimented were ignorant of the phenomena of contrast color, and moreover were misled as to what they would see on looking into the tube, and I was specially careful not to speak to them about color. These persons were strangers to each other, and neither knew that the other had been the subject of my experimenting. The first observer at once reported: "I see a circle half yellow and half blue." The other said: "I see a golden band next to a sky-blue band, and the golden band is rather deeper in color where it is next to the blue," which is certainly a very good description.

Having in mind the facts established by the foregoing experiments, it seems to me that we have either to regard the phenomena of simultaneous contrast color as psychical phenomena of which no satisfactory explanation has been given, or we must discard the Young-Helmholtz hypothesis of color sensation and adopt one similar to that of Hering, which gives a direct physiological explanation of contrast color effects without the psychological considerations which those who adopt the Young-Helmholtz hypothesis are obliged to resort to in their explanation of these phenomena; and which explanations, as I have attempted to show, are faulty, and have to be modified to be convincing.

According to Hering's hypothesis of color sensations, when a portion of the retina is stimulated, adjoining portions of the field

of view are affected by a sort of inductive action; so that changes are produced which are antagonistic or complementary to those portions of the retina actually stimulated.

M. Foster, in his "Physiology, Lond., 1891," Part IV., bk. 3, gives an excellent discussion of the relative merits of the Young-Helmholtz hypothesis and Hering's in explaining color sensations. In conclusion he writes, * * * "so far as we are aware no crucial test between the two has as yet been brought forward. We may now leave the matter with the remark, that while the Young-Helmholtz theory tends to lead us direct from the retinal image to the psychological questioning of the sensations, and seems to offer no bridge between the first step and the last, Hering's theory is distinctly a physiological theory, and at least holds out for us the promise of being able to push the physiological explanation nearer and nearer home before we are obliged to take refuge in the methods of psychology."

A Photometer for Measuring the Intensities of Differently Colored Lights.—It has already been shown that, in certain conditions of illumination and in certain directions of sight, a screen formed of perforated cardboard covered with translucent paper appears with complementary colors, and that if the screen be in the form of a disk with alternate sectors cut out of it, and is illuminated on side by daylight and on the other side by lamplight, that the blue of one side of the disk and the orange of the other appear intensified on slowly rotating the disk. On increasing the velocity of rotation the complementary colors gradually blend, and when the velocity of rotation has banished all flickering light from the disk it appears nearly white. The side facing the daylight has a slight yellowish tint; the side facing the lamp appears whiter, but is tinted with a feeble bluish hue.

To study more minutely these phenomena I made a disk which could be readily taken apart and mounted with different translucent papers, and have attached to it disks and rings of various colors. I shall call this disk, *the photometer disk.* It is made as follows:

Two disks, 13 centimeters in diameter, and having eight sectors cut out, as shown in Fig. 13, were made of thin Bristol board. A circle of 2 centimeters in diameter was left in the center of the disk, from which the cardboard sectors radiate. The border of the disk is a ring of one-half centimeter wide, which was painted black. Clamps made of thin hammered brass held these disks together.

Between these disks was placed a circle of the same white translucent paper used in the construction of the large contrast color screen, Fig. 1, and the disks were clamped together with the open sectors of the two disks coinciding in position. A black disk of 8.2 centimeters in diameter was placed on each side of the photometer disk, thus leaving between it and the black peripheral ring an annular space of 1.9 centimeters wide, formed of alternate spaces of cardboard and of translucent paper. The disk was mounted on

a rotator and placed opposite two silvered mirrors inclined at an angle of 150 degrees; an arrangement similar to that of Letheby for observing the disk of Bunsen's photometer. The plane of the disk of the rotator bisected the angle formed by the mirrors, as shown in Fig. 14, so that the surfaces of both sides of the disk could be seen simultaneously, or, rather, in rapid succession. On rotating the disk while illuminated by daylight on one side and by lamplight on the other, the side illuminated by daylight appeared white tinted with yellow; the side facing the lamp appeared white tinted with blue. The hues were the same as described in the experiment with the large disk, Fig. 8, only the surfaces appeared brighter by contrast with the black center and border.

The feeble character of the hues on the photometer disk led me to hope that I could bring these to the same hue on both sides of the disk by the effects of contrast. To accomplish this I placed

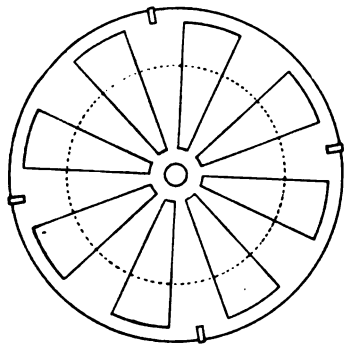

Fig.13.

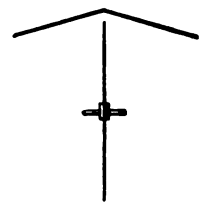

Fig.14.

on the daylight side of the photometer disk a compound disk formed of three split disks, one of red lead, one of chrome-yellow, the other of white Bristol board. On the lamplight side I placed a disk formed of three split disks, colored ultramarine, emerald-green, and one of white Bristol board. On rotation, the compound disk on the daylight side gave an orange-yellow; on the lamplight side the disk gave a bluish green. These colors corresponded in hue to those seen on the respective sides of the ring of the photometer disk when it is rotated, only the hues were much more saturated. After a few trials I brought, by the contrast effects of these colored disks, the tints on the two sides of the ring of the photometer to the same hue; the translucent ring appearing white with a very slight orange-yellow tint on both of its sides. The greenish blue had by contrast effect obliterated the blue tint of the ring and even replaced it by a very feeble orange-yellow; while on the other side of the ring the

orange-yellow disk had diminished the orange-yellow tint of the ring to the same feeble orange-yellow as seen on the other side of the ring.

Experiments were now made to test this apparatus as a photometer. Equality of illumination cannot be determined with any precision if the two surfaces compared differ even slightly in hue. Here we had the same hue to deal with on both sides of the ring; which condition is different from the Bunsen photometer on which we have two colors on each side of the disk. Various methods were tried to render reliable the comparison of the illumination of the two sides.

(1) I used the eye alone, regarding only the portions of the ring on the border near the mirror, as shown in Fig. 14.

(2) Two prisms reflected the images of portions of the sides of the ring nearest the mirror to juxtaposition, as shown in Fig. 15.

(3) A tube blackened on the inside, with a black screen on the end next the disk, as shown in Fig. 16, was used. The eye was thus

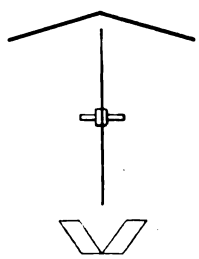

Fig.15.

Fig.16.

shielded from extraneous light and the comparisons of illuminations were made, as in experiments 1 and 2, on the portions of the rings which were nearest the mirror as shown in Fig. 16. Vision through this screened tube gave the best results.

After practice in such comparisons, made during several hours on different days, I became more and more skillful, and the results of measurements became more concordant; but such methods of photometry do not approach the accuracy of those in which two contiguous surfaces of different degrees of translucency coalesce into one surface of a uniform illumination, as happens on the balance of illuminations on the two sides of a Bunsen photometer disk when these are illuminated by lights of the same intensity and of exactly the same hue. A photometer for this mode of observation is described in the following section. It has, however, the advantage over the Bunsen photometer in that it serves to measure the intensities of differently colored lights.

The Rotating-Disk Photometer.—The photometer disk was taken apart and a ring of thin white linen paper* of the diameter of the disk and $\frac{9}{10}$ centimeter wide was laid on one of the disks; this was covered by the circle of thin translucent white paper and on this was laid another ring of the thin linen paper. The other sectored disk of cardboard was placed on these, and the disks were now clamped together. The outer portions of the open sectors of the disk were thus closed by two thicknesses of the thin linen paper with the "Alba tracing paper" between them, *a*, in Fig. 17; while the inner portions of the sectors were closed by the tracing paper alone, *b*, in Fig. 17.

On rotating the disk it was not possible to balance the colors of the outer half (*a* in Fig. 17) of the ring formed of three thicknesses of paper, with the same central colored disks, used in the

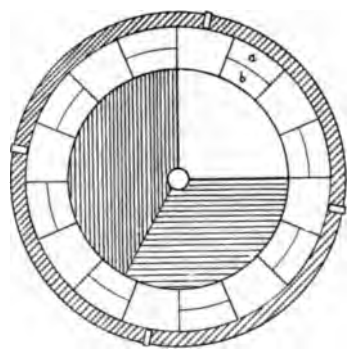

Fig. 17.

previous experiment, when one side of the disk was illuminated by lamplight, the other by daylight. But on increasing the saturation of the hues of the central disks and adding peripheral rings of the same hues, I succeeded in making the hues the same on both sides of the photometer ring. If equality of hue can be obtained when the photometer is illuminated, on one side by lamplight and on the other by daylight, then the contrast colors may be brought to the same hue when the photometer is illuminated on one side by a candle or petroleum flame, and the other side by the electric arc light or by the whitest Welsbach incandescent lamp.

With a change of distance of the petroleum flame from the photometer, the differences in the illumination of the portions *a* and *b*, Fig. 17, of the ring were changed. When the two sides of the

* The best paper I have experimented with for this purpose is watermarked "Crane & Co., Dalton, Mass., Bond, No. 21."

ring were equally illuminated the rings *a* and *b* appeared indistinguishable, fusing into one ring of uniform tint and illumination, of the breadth of $a + b$.

With the best Bunsen photometer disk* I was unable to decide where it received equal illumination on its sides, so difficult was it to judge of equal brightness of the blue and orange on one side when compared with the orange and blue in the same respective positions on the other side of the disk.

With a petroleum flame of 40 candle light-giving power on one side of the rotating photometer and a candle on the other, the delicacy of the indications of the rotating photometer equaled, and even slightly excelled, those of the very best Bunsen photometer disk.

If we bring in succession the translucent sectors of the rotating photometer disk between two lights we observe that, on certain sectors, *a* and *b* appear as one surface of the same uniform tint and illumination; on other sectors sometimes *a*, sometimes *b*, is the brighter. Rotation of the disk entirely destroys such slight differences, and the disk then acts as if made of absolutely homogeneous material, placed in the same conditions of contact of the layers of paper, in each translucent sector.

The Hue of the Light of "a White Incandescent Welsbach Lamp" Compared with Daylight.—When the screen, Fig. 1, is illuminated on one side by the Welsbach lamp and on the other by daylight, the side of the ring of the screen facing the daylight appears a feeble blue decidedly tinged with violet. The side of the ring facing the Welsbach lamp is colored greenish orange. This greenish orange was matched in hue, but not in luminosity, by a rotating disk having 41.5 parts of red lead, 41.5 parts of chrome-yellow, and 17 of emerald-green, viewed illuminated by daylight. This appears to be the hue of the Welsbach light when compared with daylight.

Experiments in which are Compared the Hues of the Light of an Incandescent Welsbach Lamp and of Candle-Light.—When "a white light incandescent Welsbach lamp" is placed on one side of the large screen, Fig. 1, and a candle, or petroleum flame, on the other side, the cardboard ring of the screen facing the Welsbach light appears of a light bluish green; the side of the ring facing the candle, or petroleum flame, appears of a light carmine.

Matching these hues on the rotator with split disks gave the following results when the two sides of the screen were equally illuminated. The hue of the ring on the side facing the Welsbach lamp was matched by 8 parts of emerald-green, 10 of cobalt-blue, 25 of ivory-black, and 57 parts of white Bristol board, as seen illuminated by the Welsbach lamp. The hue on the side of the ring facing the candle or petroleum flame was matched by 12 of carmine,

*The best Bunsen photometer disks I have used are those sold by the American Meter Company of New York. They are made in England.

17 of ivory-black, and 71 of white cardboard, as seen illuminated by the petroleum flame.

Experiments with the Rotating-Photometer Disk Placed Between the Welsbach Lamp and the Petroleum Flame.—On rotating the photometer disk, without any central disks, between these lights, the same hues as those already described were seen on its sides, only these hues were much less saturated.

The white disks placed on the sides of the rotating photometer made the hues less saturated.

With a white disk on the petroleum flame side and a black disk on the Welsbach lamp side the difference between the hues of the sides of the photometer was more pronounced.

With a disk of cobalt-blue, emerald-green, and white on the Welsbach light side and a white disk on the petroleum flame side, the side of photometer facing the Welsbach lamp appeared white and the side facing the petroleum flame was less carmine; the differences in hue being less than in any of the previous experiments.

By trial I found that when a disk of 33 parts of emerald-green, 42 of cobalt-blue and 25 of white was placed on the Welsbach lamp side of the photometer disk, with a ring of the same hue on the periphery, and a disk of 75 parts of carmine and 25 of white was on the petroleum flame side of the photometer disk, with a ring of the same hue on the periphery of the photometer, that the sides of the photometric ring of the photometer had the same hue; which was white-tinged with just a perceptible carmine.

We are now in condition to make an interesting experiment, which shows in a striking manner the effects of the colored central disks and peripheral rings on the colors of the photometric ring of the photometer. The exact balance of hue on both sides of the photometer has been obtained. Reverse the photometer disk with its central disks and rings and rotate the disk in front of the mirrors. We now see the photometric ring with strong contrast of color on its sides, and the concentric rings *a* and *b* are separately seen, not appearing indistinguishable as in the previous experiment. By the reversal we have, by the effects of the colored disks and rings, added to the effects produced alone by the lights.

It is to be noted that the colors on the disks and rings of the photometer must not be too saturated in hue. The elementary disks of these compound color disks should be made of thin Bristol board, and after they have been painted should be well flattened before they are slit radially. After the proper hues have been obtained for the disks which correct the color of the photometric ring, the same hues should be painted on single disks, which are subsequently flattened. The thinner the color-correcting disks and the closer they fit to the photometer disk the greater is their contrast color effect. The colored rings must be cut out of the painted cardboard, for if the rings are painted after they are formed it is very difficult to make them flat.

To render easy the making of this photometer, I made experiments so that one could get the proper hues of the correcting disks and rings by mixtures of definite weights of the pigment powders and definite volumes of gum water; but it is less troublesome to paint a few disks with colors variously saturated and repeat the experiments I have described, and thus furnish oneself with the sets of disks and rings necessary for the photometric measures of the arc electric light, of the Welsbach white burner, etc., when compared with the standard candle or petroleum flame.

The rotator on which the photometer disk is revolved should be made as shown in Fig. 18, so that the standard S, and the pulley P, which is driven by the wheel W, shade as little as possible the rotating disk D D.

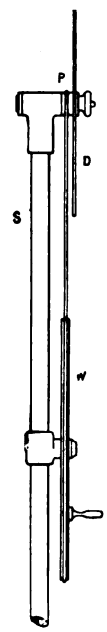

Fig. 18.

Photometric Measures with the Rotating-Disk Photometer.—On one side of the photometer was placed "a white Welsbach burner" with a light-giving power of 33 candles, on the other side a standard candle. As the candle was gradually brought nearer the rotating photometer the illumination and hues of the portions *a* and *b* (Fig. 17) of the photometric ring approached equality, and when the candle was at a certain distance the difference of illumination and hues of *a* and *b* become indistinguishable and only a band with a breadth of $a + b$ with a uniform surface was observed on the sides of the photometric ring.

The measures of the intensity of the light of the Welsbach lamp in terms of the standard candle were made by a friend. He made 16 measures with my rotating-disk photometer and 16 with the Bunsen photometer.

The mean of the series of measures made with the rotating-disk photometer differed from the mean of the departure of the maximum and minimum measures from the mean by 1.49 per cent. of the mean intensity of the light of the Welsbach lamp.

The mean of the series of measures made with the Bunsen photometer differed from the mean of the departure of the maximum and minimum measures from the mean by 5.22 per cent. of the mean intensity of the light of the Welsbach lamp.

ATHLETICS.

A NEW football league has been formed this season, with Lafayette, Rutgers, and Stevens as members.

The games scheduled are as follows:

October 21, Stevens *vs.* Rutgers, at New Brunswick.

October 25, Stevens *vs.* Lafayette, at Hoboken.

November 11, Rutgers *vs.* Lefayette, at Easton.

Games have also been played: With the Orange Athletic Club at Orange on September 30; score, Orange A. C., 12; Stevens, 0. With Crescent Athletic Club at Hoboken, October 4; score, Stevens, 10; Crescents, 8; and the return game with the Crescents at Bay Ridge on October 10; score, Crescents, 16; Stevens, 0. Also with College of City of New York on October 18; score, Stevens, 60; C. C. N. Y., 0.

The league game on October 21 was won by Stevens in two 30-minute halves; score, Stevens, 38; Rutgers, 8.

The teams lined up as follows:

Stevens.		*Rutgers.*
Kellogg	Left end	Van Hee.
Hutchinson	Left tackle	Mohn.
McIlwain	Left guard	Carpender.
Gallaher	Centre	Conover.
Lançon	Right guard	Ranney.
Campbell	Right tackle	Dyke, Captain.
Kemble	Right end	Seigler.
Coyne, Captain	Quarter back	Denise.
Brown	Left half back	Mason.
Cuming	Right half back	Ludlow.
Fielder	Full back	Poland.

Referee, Mr. Farrand, of Princeton.

Umpire, Mr. Edwards, of Lafayette.

The second league game, decisive as to the championship, was hard fought, and the play of the Stevens men, though defeated, was highly creditable alike to them and to their captain, Frank Coyne.

Two 30-minute halves were played, resulting in the score, Stevens, 10; Lafayette, 12.

Stevens.		*Lafayette.*
Kellogg	Left end	Edwards.
Hutchinson	Left tackle	Bieber.
McIlwain	Left guard	Roland.
Gallaher	Center	Jordan.
Lançon	Right guard	Reinhart.
Campbell	Right tackle	Boericke.
Kemble	Right end	Miller.
Coyne, Captain	Quarter back	Bloomberg.
Cuming	Left half back	Smith.
Brown	Right half back	Voight.
MacCord	Full back	Sigman.

Referee, Mr. Alexander, of Wesleyan.

Umpire, Mr. Farrand, of Princeton.

INSTITUTE NOTES.

THE OFFICERS of the Stevens Alumni Association for the current year are: President, Harry Van Atta; Vice-President, Durand Woodman; Recording Secretary, J. Day Flack; Corresponding Secretary, Phillip E. Raqué; Treasurer, W. H. Bristol; Directors for one year, W. L. Lyall, Robert Dixon; Directors for two years, William Sheldon, Joseph A. McElroy.

PROFESSOR RIESENBERGER, who has, though unknown to all but a few of his friends, been in poor health for several months, is now seriously ill with typhoid fever. It is to be hoped that his great vitality will enable him to recover rapidly. Even then, the tedious nature of the disease will preclude his return to the Institute this term. Arrangements have been made with Mr. F. E. Idell, '77, to take Professor Riesenberger's classes during the latter's absence.

"HOW TO THINK IN GERMAN," the second book of Professor Krœh's series on the "Living Method" for the oral acquisition of foreign languages, has appeared, and is meeting with equal favor to that accorded his first work of the series, "How to Think in French."

UNDER PROFESSOR GEYER'S supervision, the new dynamo room is being wired in the most convenient and systematic manner. A number of new rheostadts and other apparatus have been purchased, and three motors have been presented to the Institute by the General Electric Company, all of which are being arranged so as to be available for experiment by the students.

THE ELECTRICAL DEPARTMENT has recently conducted a series of experiments with torpedoes for Mr. E. W. Frazar, '90, of the Edison-Sims Electric Torpedo Company.

THE INSTITUTE has just received from the Blake Pump Manufacturing Company the gift of a steam pump for supplying water under high pressure to drive a Pelton water wheel for the experimental course.

MR. J. H. WICKSTEED, of Leeds, England, recently visited the Institute, accompanied by Mr. G. C. Henning, '76, desiring to see the practical side of the course of instruction here. Mr. Wicksteed, as Managing Director of Joshua Buckton & Co., Limited, Leeds, is one of the most successful manufacturers of testing machines, and naturally gave especial heed to methods and apparatus employed by the Department of Experimental Mechanics, and also was greatly interested in the recording devices shown him by Professor Bristol.

THE CONNECTION of members of the class of '92 with the construction of the train shed of the new Union Depot in Boston, of the Boston and Maine Railroad, is worthy of note. This shed is 500 feet in length, con-

tains 22 tracks, and is designed to provide for 740 trains in and out daily. Messrs. F. W. Cohen and William C. Cuntz worked on the drawings of this structure, in the draughting room of the Pennsylvania Steel Company. A. R. Hake, in the rolling mill of the same company, had a part in getting out the material. H. D. Whitcomb, on behalf of Hildredth, Dod & Co., the firm of inspectors employed by the railroad company, inspected the material. William C. Cuntz is now superintending the erection of the shed for the Pennsylvania Steel Company. O. C. Whitney is putting in the gas plant for the Pintsch Lighting Company. H. C. Meyer is working up details of the power plant, in the employ of George H. Barrus, who has been retained by the railroad company to lay out the power station for the shed. Thus, six Stevens graduates of '92, in the employ of four different firms, have taken part in the design, construction and equipment of this one structure.

A list of the members of the Freshman Class of '97 is given herewith:

H. W. Anderson, E. Orange, N. J.
H. L. Backus, Savannah, Ga.
L. Baldasano, New York City.
E. O. Ball, Elizabeth, N. J.
W. J. Beach, Jersey City, N. J.
A. Beutler, Jr., New York City.
Robert Boettger, Hoboken, N. J.
P. J. Brune, New York City.
S. F. Butterworth, Morristown, N. J.
Edw. Calix, Jr., Hoboken, N. J.
D. Campbell, Cold Spring, N. Y.
W. Chapin, Brooklyn, N. Y.
J. T. Charlton, Savannah, Ga.
C. R. Christy, Jr., Stanford, Conn.
F. Cimiotti, Verona, N. J.
L. W. Colquitt, South Orange, N. J.
Jacob Cromwell, Baltimore, Md.
W. M. Darbee, Brooklyn, N. Y.
T. S. Dates, Pacific, N. J.
W. Davey, Jersey City Heights.
W. F. Doughty, Brooklyn, N. Y.
L. A. Elleau, Maplewood, N. J.
W. D. Ennis, Paterson, N. J.
A. S. Evens, New York City.
L. Garrick, Jersey City, N. J.
C. B. Grady, Orange Valley, N. J.
Geo. Hammond, New York City.
W. S. Handforth, Hoboken, N. J.
Chas. Hidden, Far Rockaway, L. I.
H. L. Holbrow, New York City.
Jas. F. Hunter, Baltimore, Md.
W. M. Hussey, New York City.
G. L. Hutchins, Brooklyn, N. Y.
F. W. Jost, Jersey City.
O. M. Kelly, New York City.
Walter Kidde, Hoboken, N. J.
W. A. Kirkland, Jr., New York City.
C. R. Knapp, Redbank, N. J.
F. A. Koch, New York City.
Geo. L. Lançon, Hoboken, N. J.
R. H. Lane, New York City.
H. Le Massena, Newark, N. J.
T. Le Massena, Newark, N. J.
Leon. B. Lent, Hoboken, N. J.
A. B. Macbeth, Greenville, S. C.
A. H. Maidment, Hackensack, N. J.
W. E. Mallalieu, Jersey City Hgts.
H. B. Mallory, Danbury, Conn.
H. C. Mathey, Hoboken, N. J.
H. M. McIlwain, Chicago, Ill.
Wm. Mehrbach, New York City.
C. L. Meister, Brooklyn, N. Y.
E. G. H. Meyer, Jr., Jersey City Hgts.
L. S. Millard, Danbury, Conn.
A. B. Miller, Montclair, N. J.
H. S. Morton, Hoboken, N. J.
E. J. Munby, South Orange, N. J.
Chas. Z. Newell, New York City.
F. Ophüls, Brooklyn, N. Y.
A. M. Orr, Jr., New York City.
F. L. Pryor, Newark, N. Y.
E. P. Reiss, Brooklyn, N. Y.

S. P. Richardson, New York City.
R. V. Rose, Niagara Falls, N. Y.
M. Ruggles, Westfield, N. J.
F. H. Sawyer, New York City.
Herman Schmidt, Hoboken, N. J.
A. S. Schweizer, New York City.
F. E. Scott, Jersey City Heights.
A. De Los Smith, New York City.
Edw. Steinbrügge, Jr., N. Y. City.
Thos. L. Terry, Englewood, N. J.
W. I. Thomson, Newark, N. J.
H. D. Tieman, Brooklyn, N. Y.
J. M. Towne, E. Orange, N. J.
J. Van Brunt, Hackensack, N. J.
E. C. Warren. New York City.
A. E. Weichert, Hoboken, N. J.
P. S. Whitman, Pennsylvania.
A. H. Wilkens, Hoboken, N. J.
G. Williamson, Wyoming, N. J.
J. Williamson, Jersey City Heights.
H. L. Woolson, Passaic, N. J.
E. N. Wood, Hoboken, N, J.
D. A. Youngs, Summit, N. J.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'78.

FRANK C. JONES, for years General Superintendent of the New York Belting and Packing Company, is now identified as President with the Manhattan Rubber Manufacturing Company, a new corporation, of which W. W. Dasheill, '79, is also one of the incorporators and Directors.

The company's factory, which will be one of the best arranged and best equipped in the United States, is at Passaic, N. J., and the office and salesroom are at 64 Cortlandt Street, New York City.

'79.

W. W. DASHIELL, of the firm of W. W. Dasheill & Co., formerly carrying on business in general machinery supplies at 2 and 4 Stone Street, New York City, has removed to 64 Cortlandt Street, where the firm is now located.

'83.

ARTHUR P. HENDERSON has left the Newport News Shipbuilding and Dry Dock Company, and is now in the Construction and Repair Department of the Norfolk Navy Yard, Norfolk, Va.

'85.

EDWIN BURHORN has given up his position as Chief Draughtsman of The Link Belt Engineering Company, to enter the firm of Warren & Burhorn, opening an office at 136 Liberty Street, New York City, as agents of Stearns Manufacturing Company.

'87.

J. H. CUNTZ was employed by the Electrical Department of the World's Fair, and also took part in the engine tests made by Dr. Emery.

CARTER H. PAGE, Jr., has been transferred from the Gate City Gas Light Company, at Atlanta, Ga., to the home office of the United Gas Improvement Company, in Philadelphia, Pa.

'90.

HARRY P. JONES is in the employ of J. & W. Lyall Machine Works, 540 West Twenty-third Street, New York City.

HENRY S. LOUD and FRANK MOYNAN, employed by the Illinois Steel Company, have been sent abroad during the temporary shutting down of the works to study European practice.

'91.

WILLIAM S. ACKERMAN is Chief Engineer of the National Lead Company, at 1 Broadway, New York City.

C. H. MCCULLOUGH is one of the party sent to Europe by the Illinois Steel Company to note methods employed in the leading establishments in their line.

'92.

HAROLD B. ATKINS is setting up a plant for the Pintsch Gas Company at St. Augustine, Fla.

WILLIAM C. CUNTZ is in Boston, superintending the erection of the new train shed which the Pennsylvania Steel Company is building for the Boston and Maine Railroad.

LUCAS FERNANDEZ, who is Assistant Engineer of Public Works at San Jose, Costa Rica, has been appointed a Commissioner of Education.

HOWARD F. GURNEY is in the employ of the Sprague Electric Elevator Company, Cortlandt Street, New York City.

JOHN T. SCHRAMME and C. F. VOGELIUS have completed the course in electrical engineering at Columbia College.

'93.

R. E. CHANDLER is Professor of Mechanical Engineering in the Agricultural College at Bozeman, Mont.

HERMAN F. CUNTZ assisted Professor Jacobus in testing work in connection with the Bureau of Awards in the Machinery Department of the World's Fair.

F. J. MEYSTRE is in the employ of the United Gas Improvement Company, at the Paterson Gas Works, Paterson, N. J.

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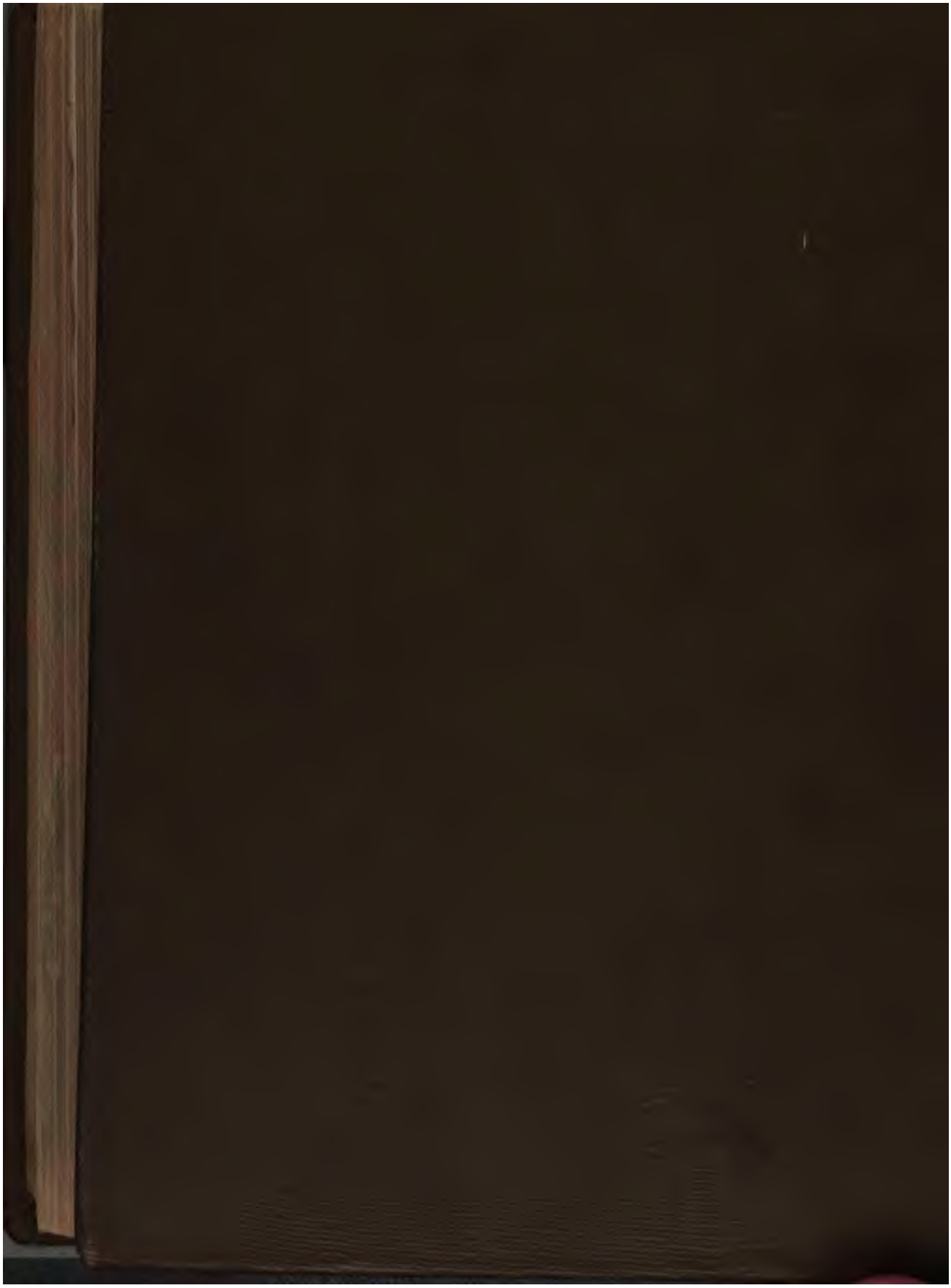
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